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(54) **TRANS-APICAL IMPLANT SYSTEMS,  
IMPLANTS AND METHODS**

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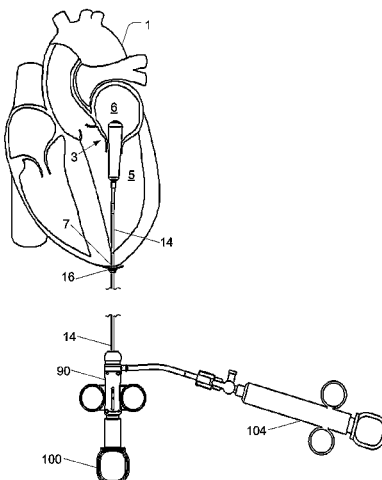
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(57) **ABSTRACT**

A trans-apical implant includes a spacer defining spacer cavity configured to be expanded from a retracted position, a shaft extending from the spacer, the shaft defining an inflation lumen fluidly coupled to the spacer cavity and configured to be fluidly coupled to an expansion medium source, and a spacer valve assembly disposed within at least one of the spacer or shaft, the spacer valve assembly configured to allow selectively allow an expansion medium to flow into the spacer cavity to be selectively expand the spacer from a retracted position to an expanded position.

**18 Claims, 22 Drawing Sheets**



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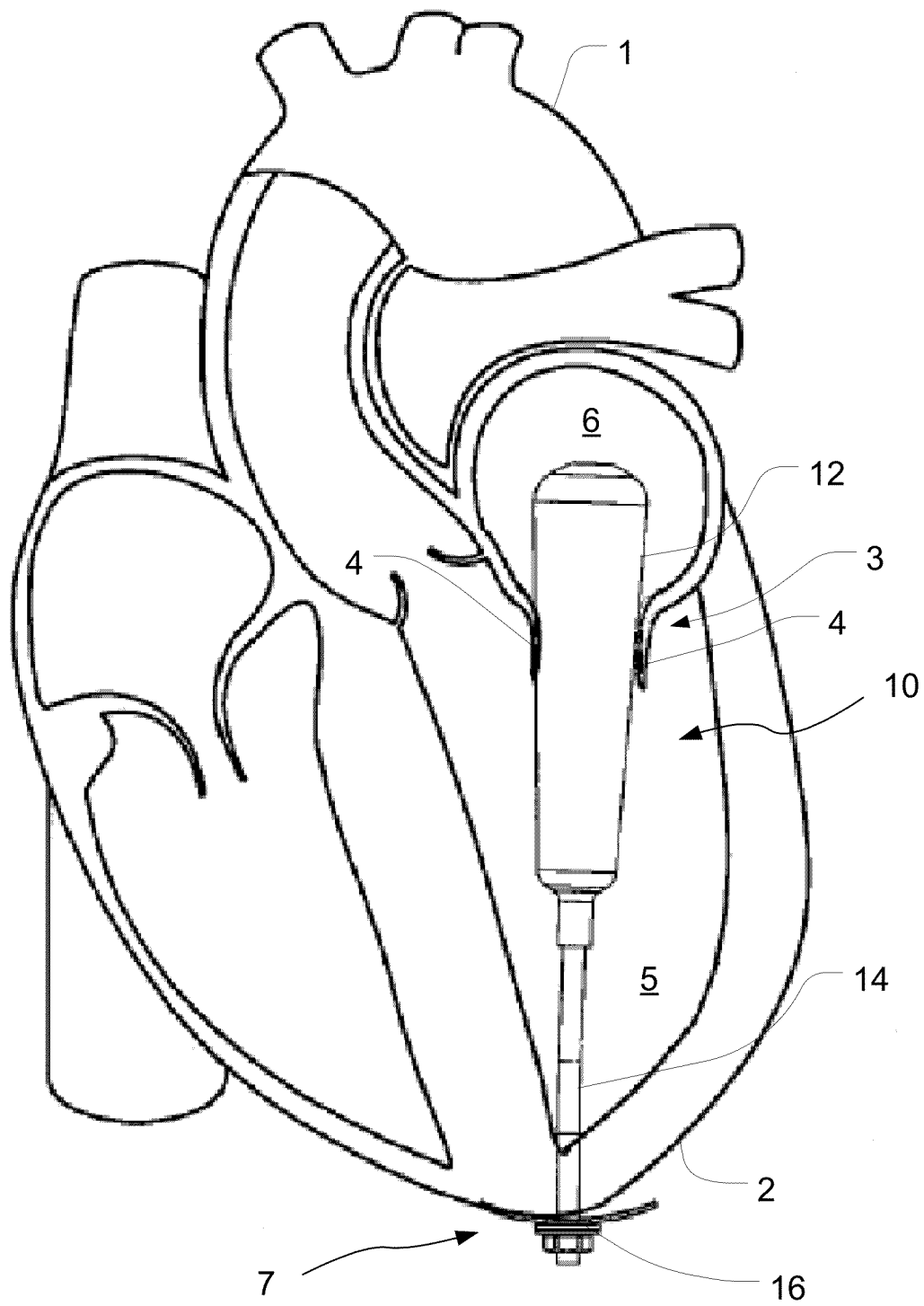
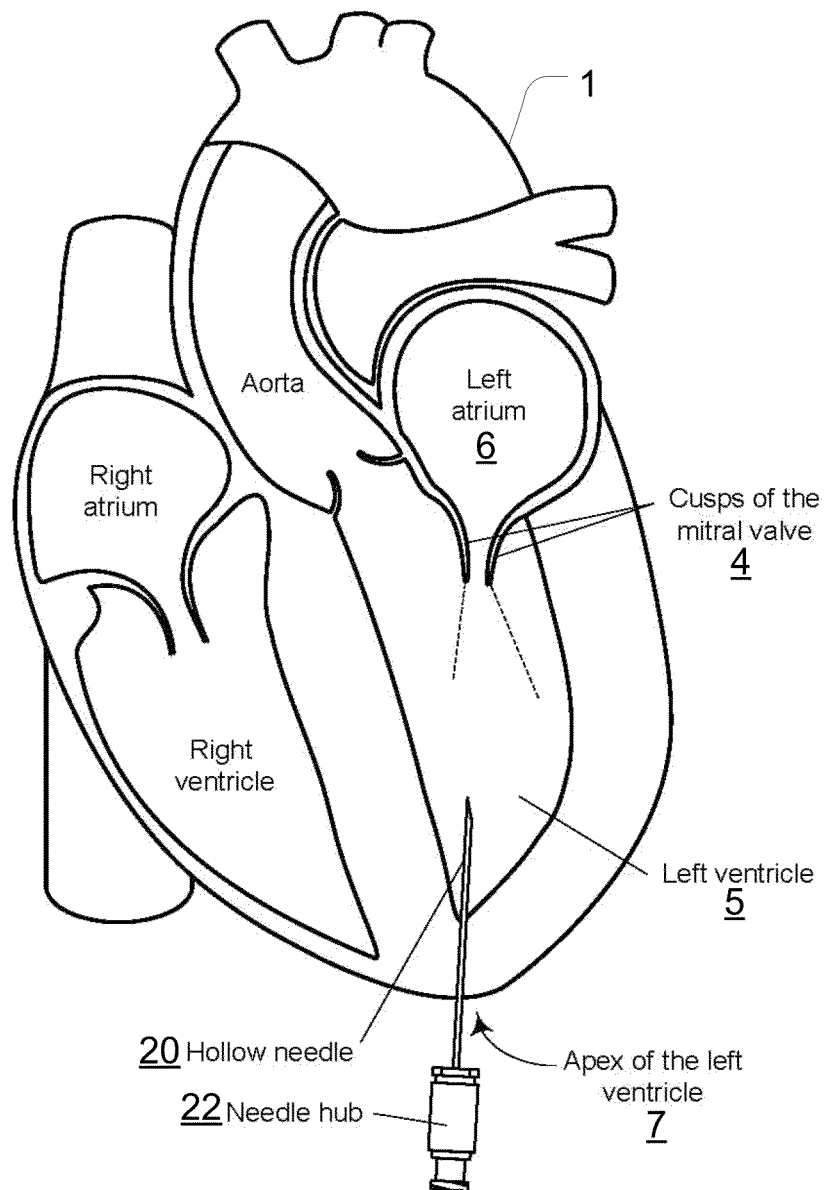
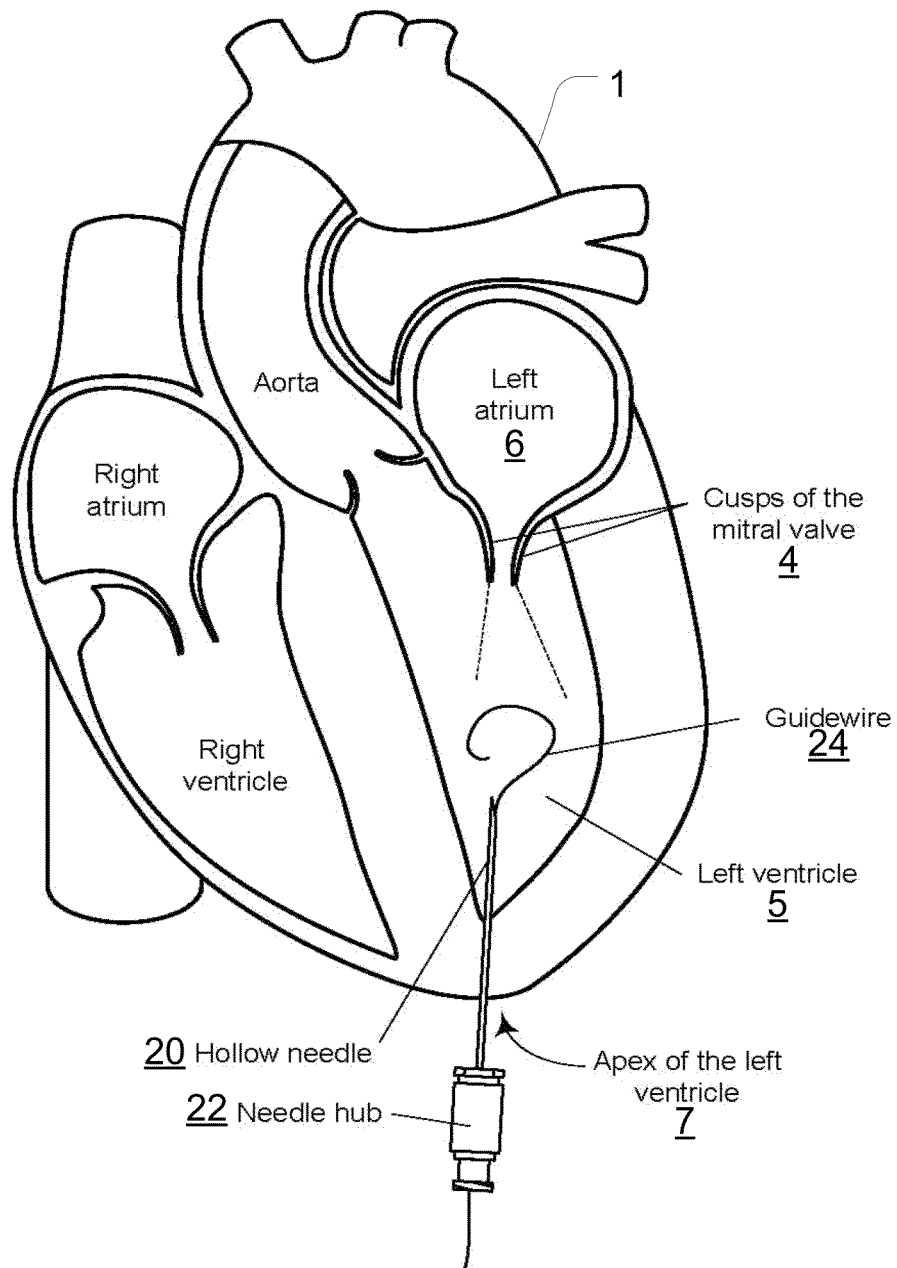
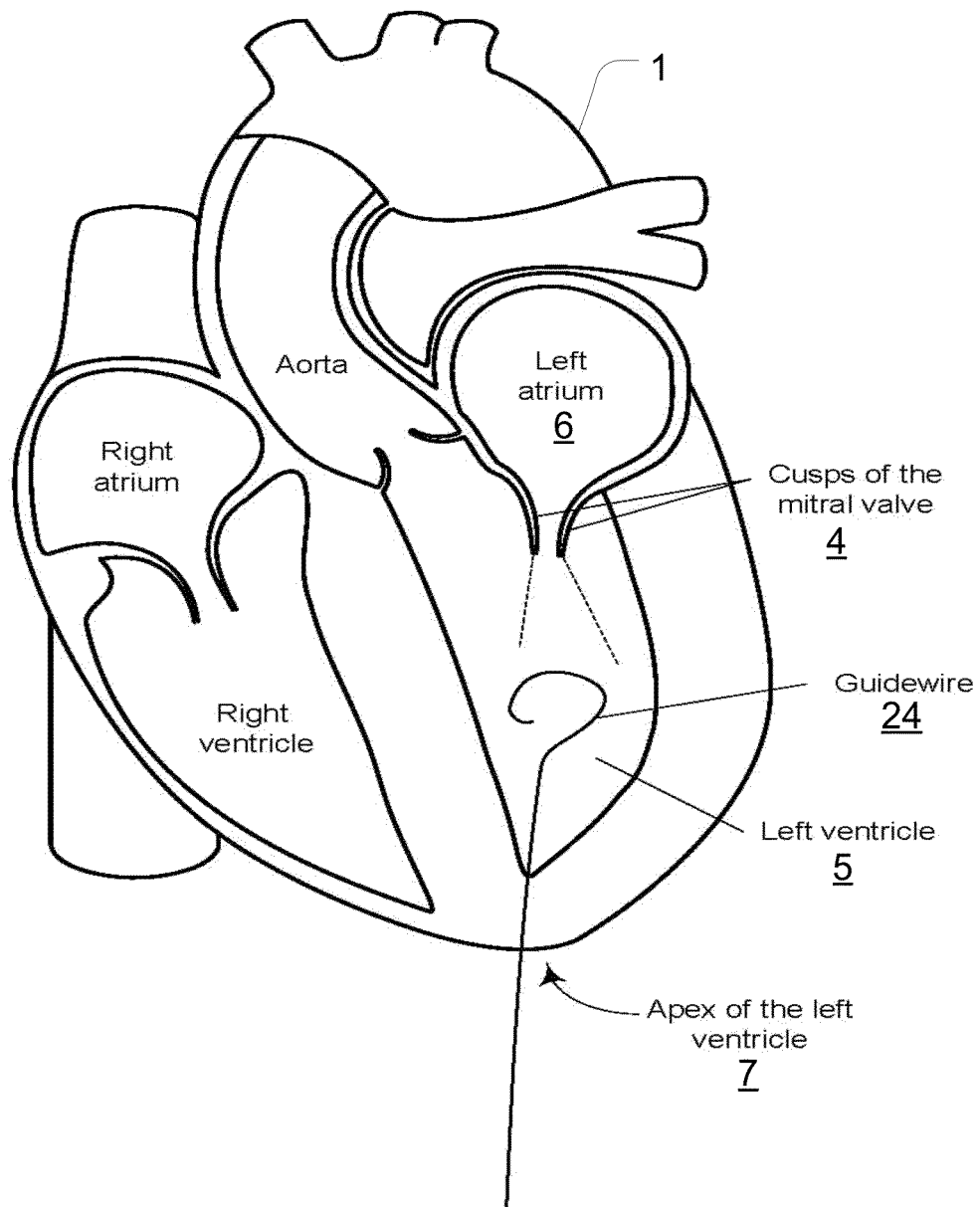


FIG. 1

**FIG. 2**

**FIG. 3**

**FIG. 4**

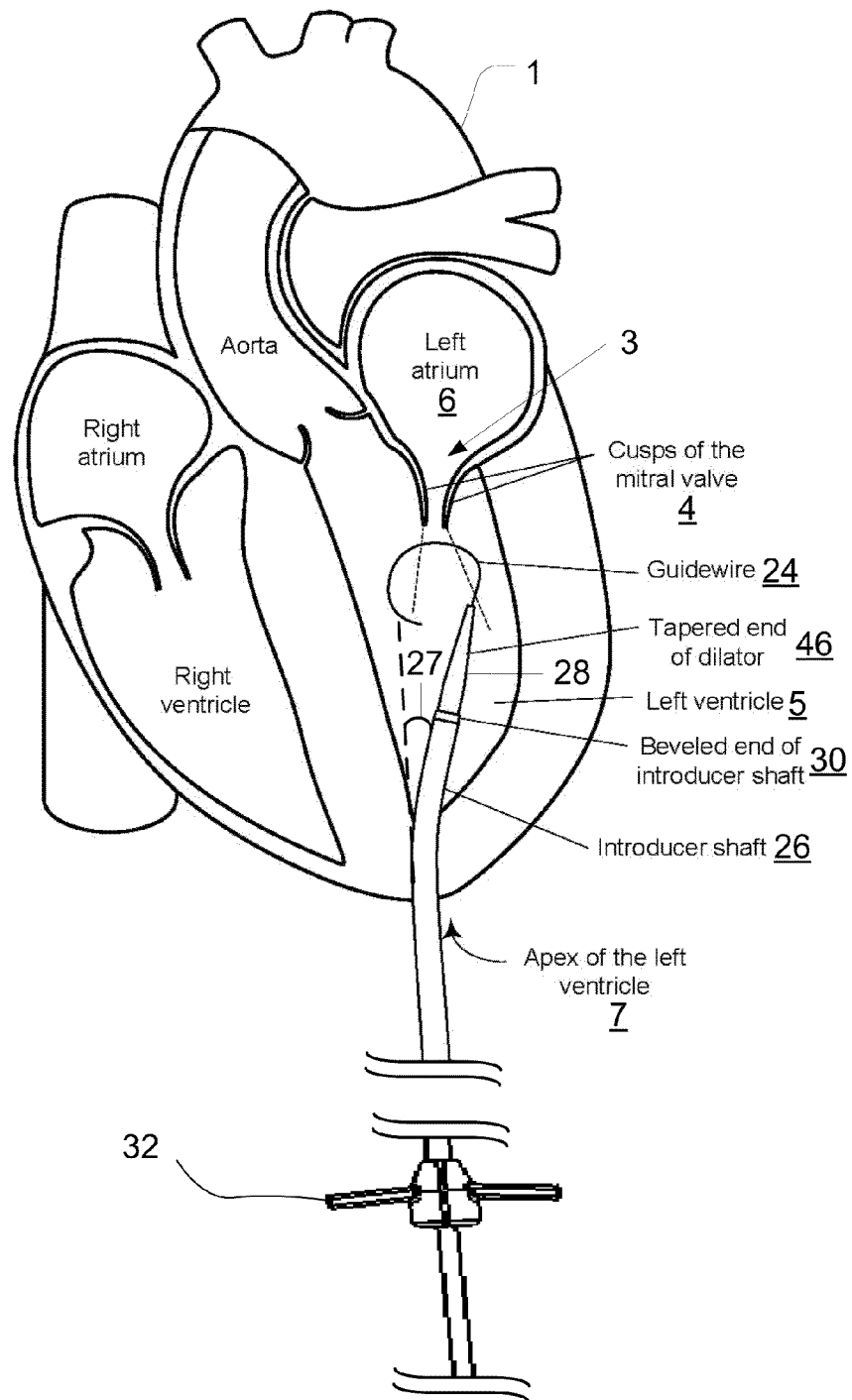


FIG. 5

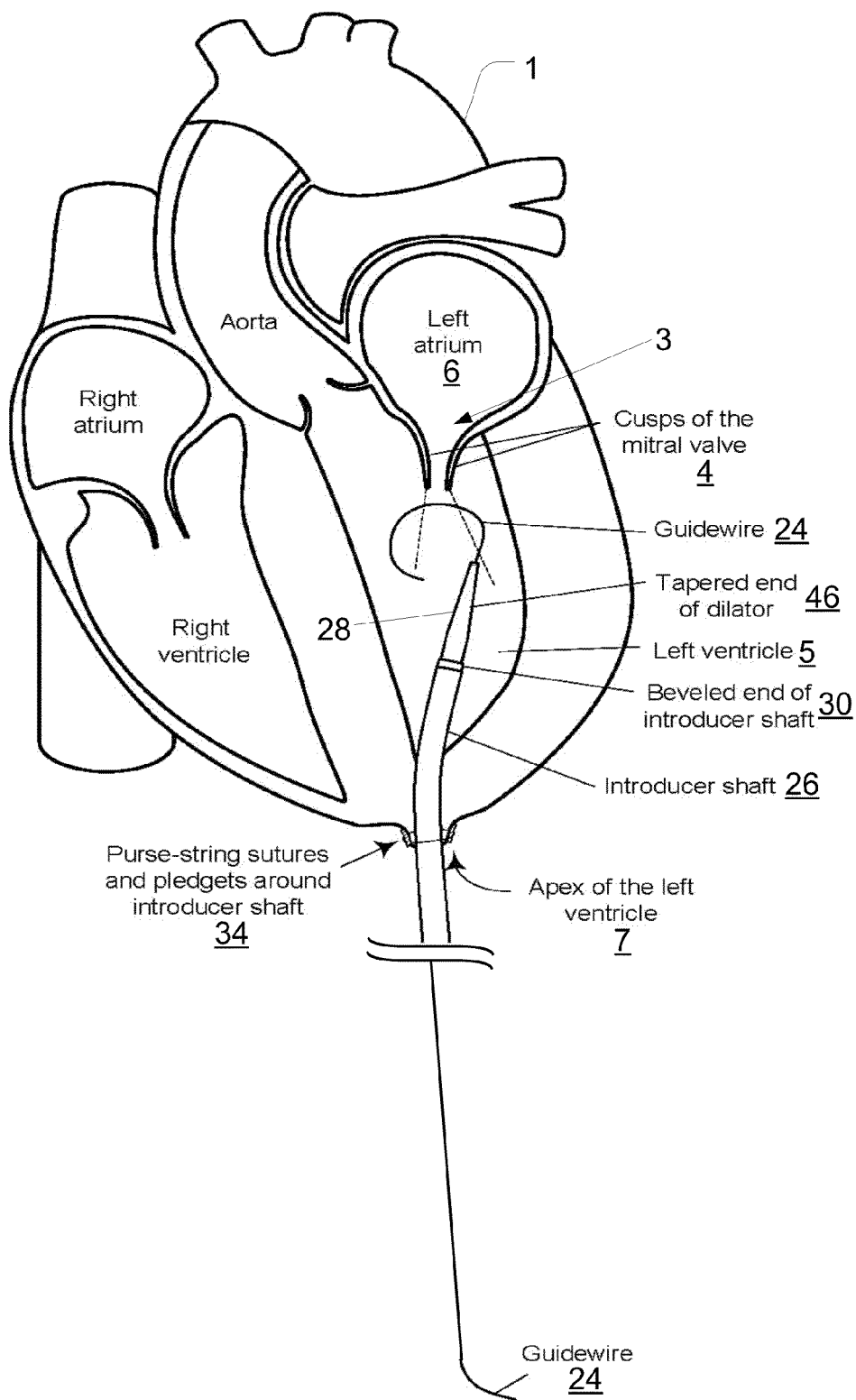


FIG. 6

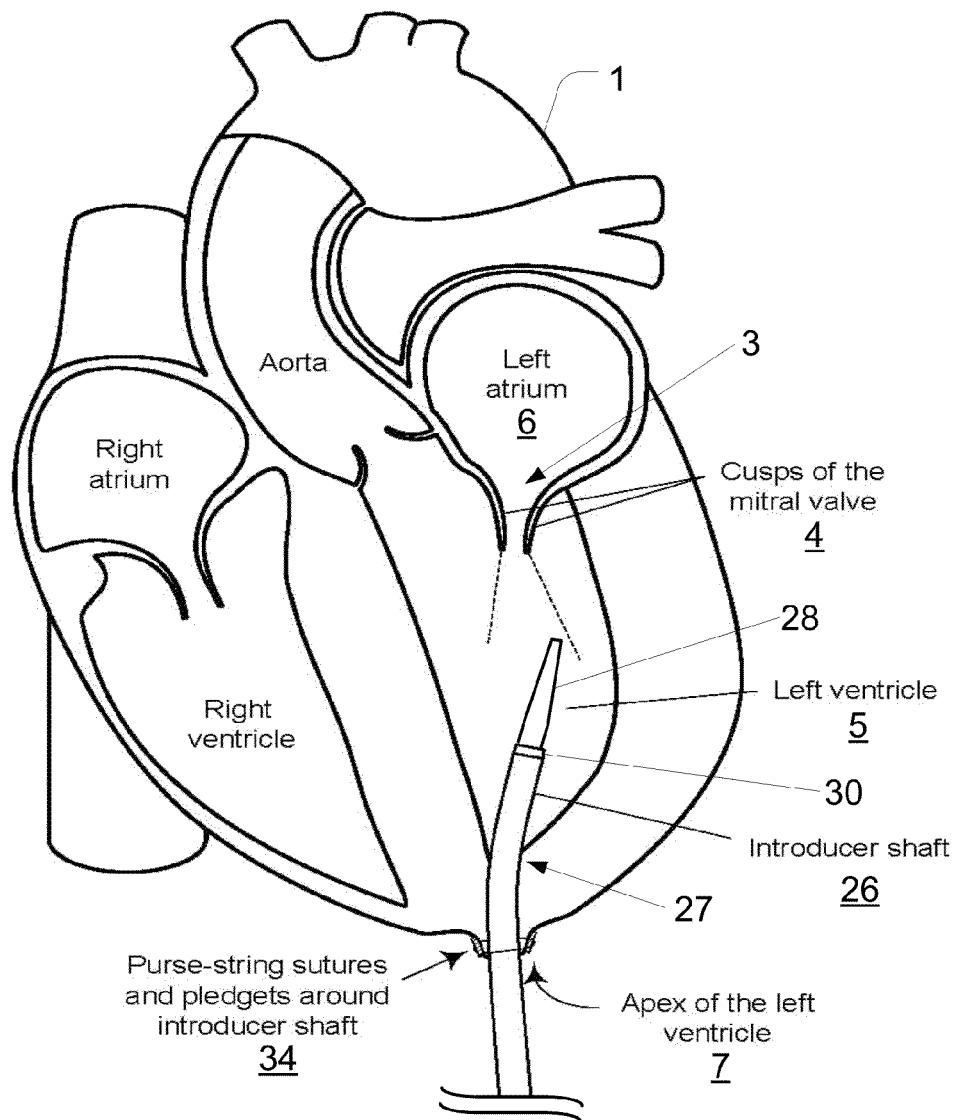
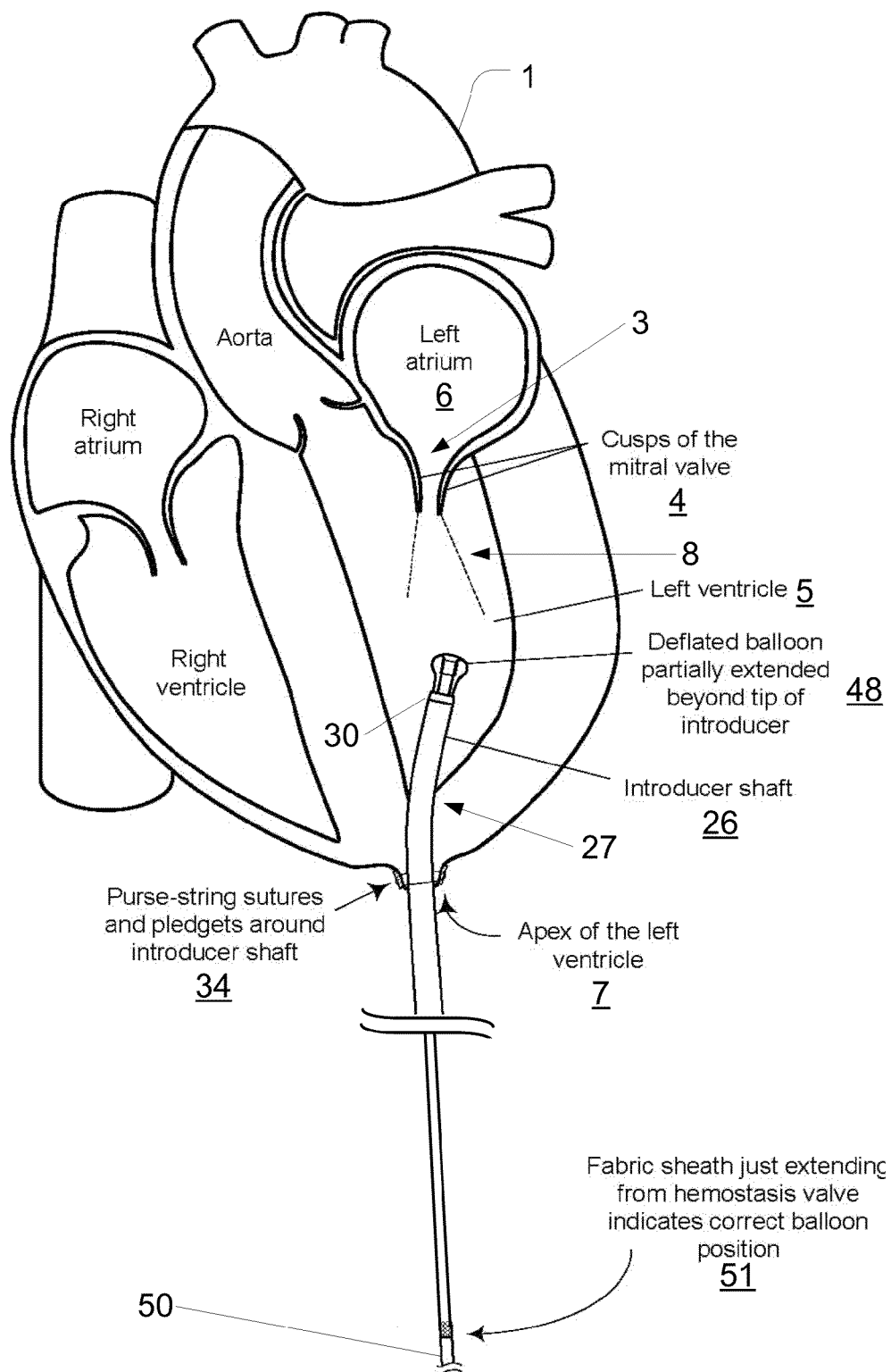


FIG. 7

**FIG. 8**



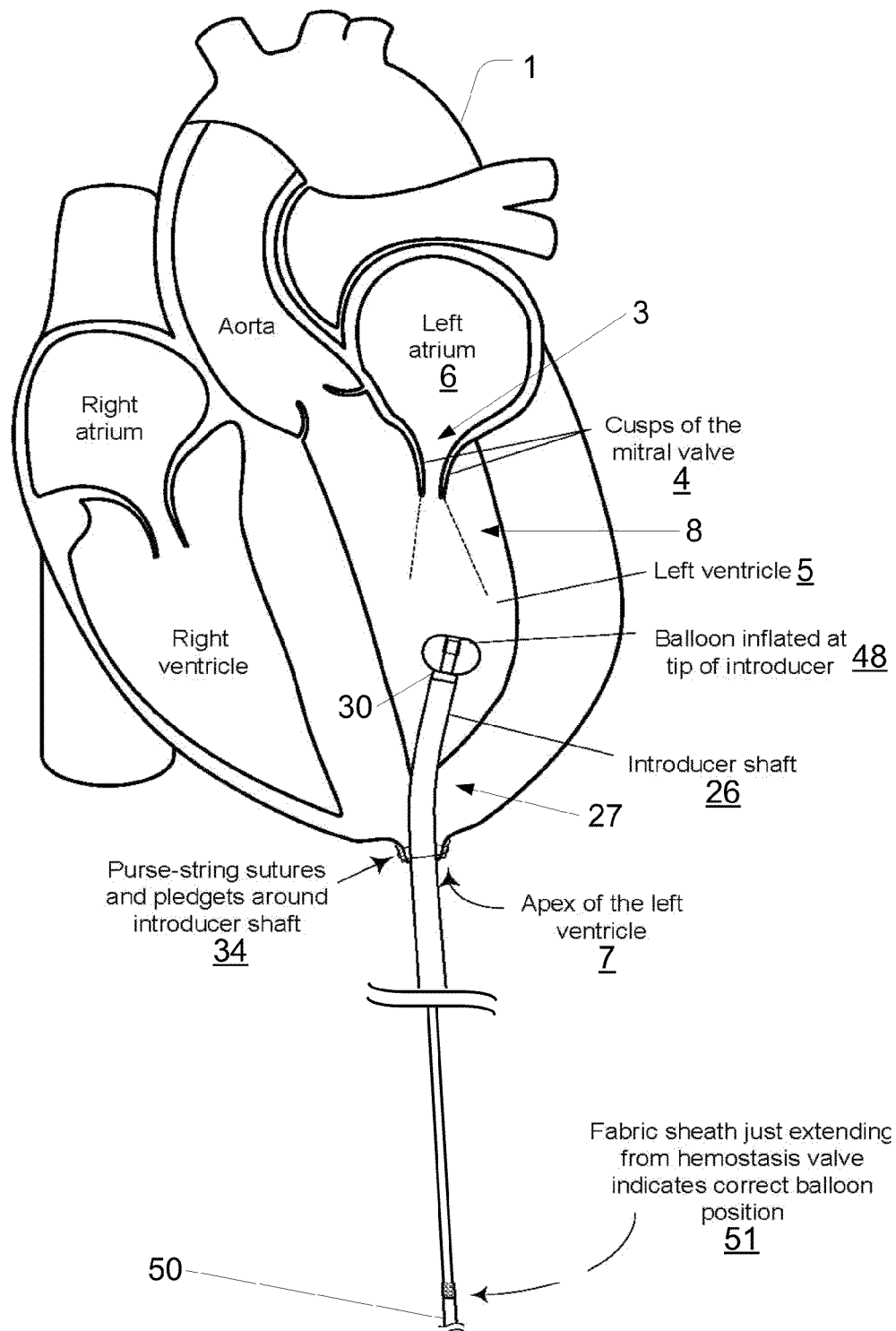


FIG. 9

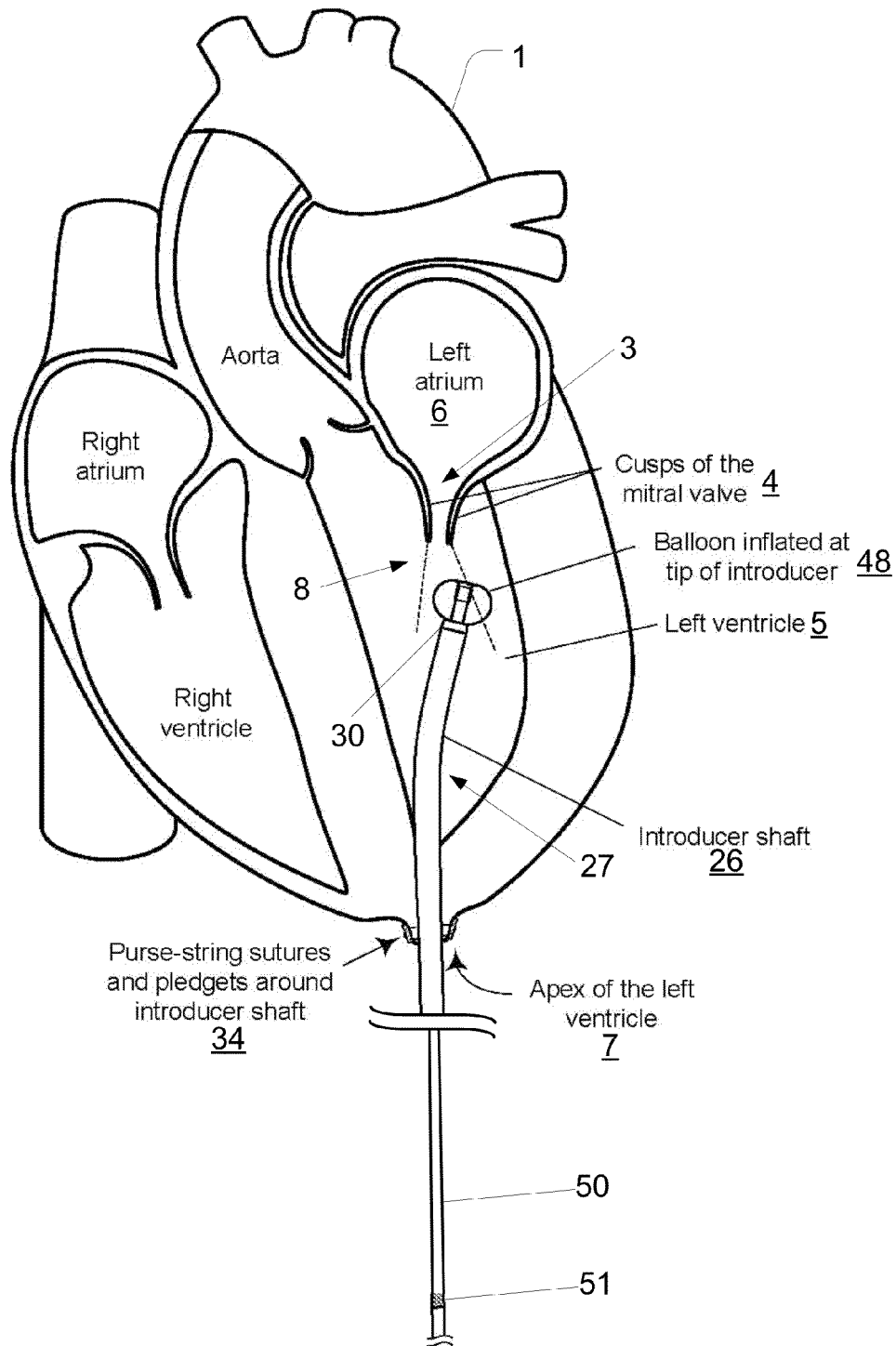


FIG. 10

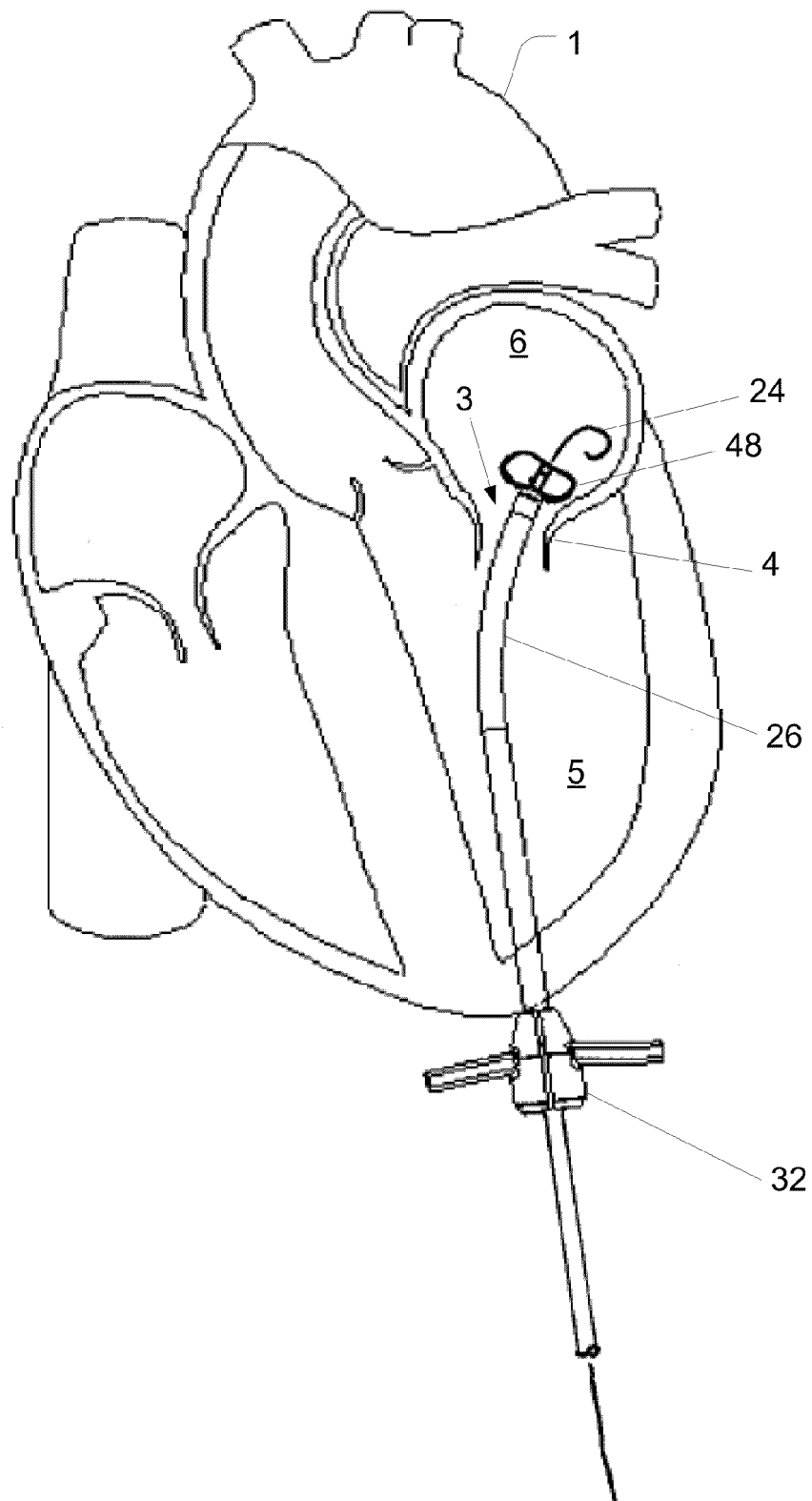


FIG. 11

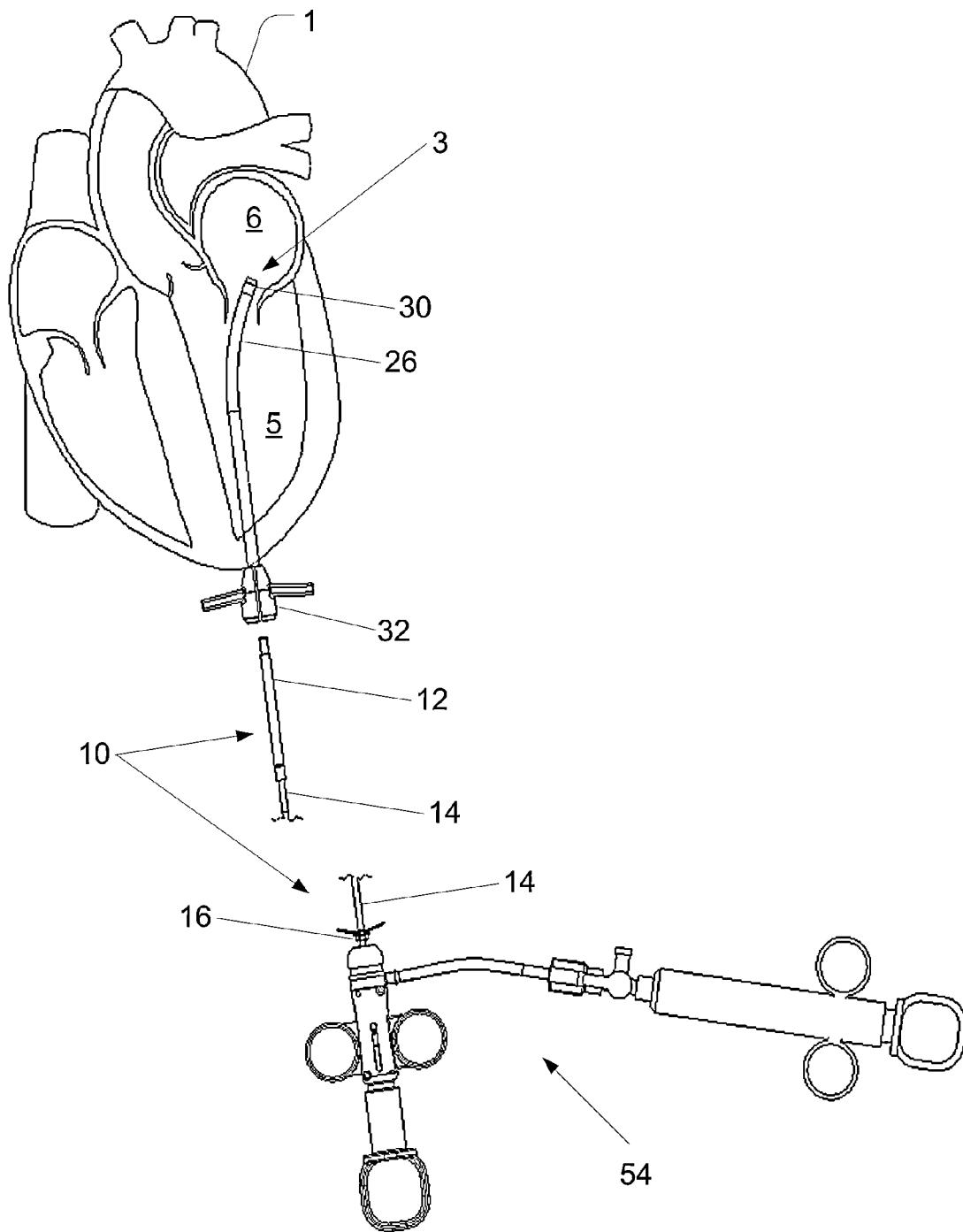


FIG. 12

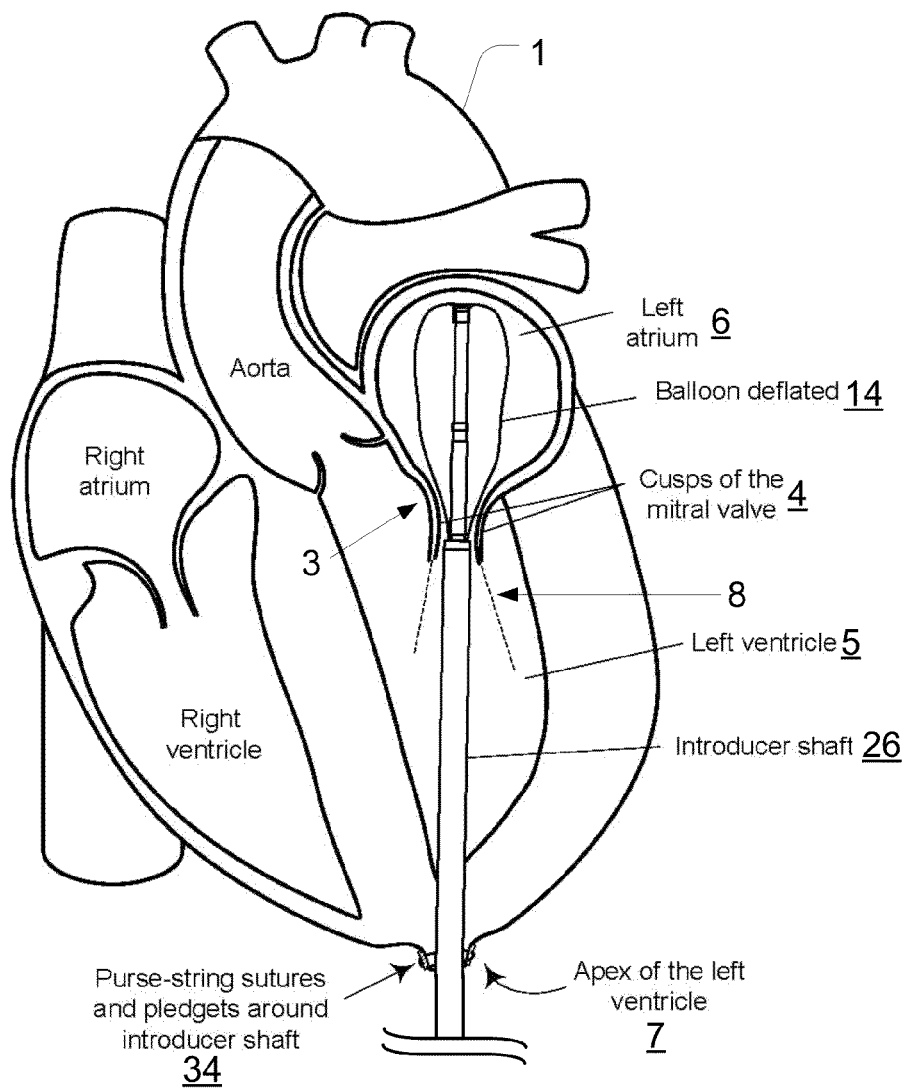


FIG. 13

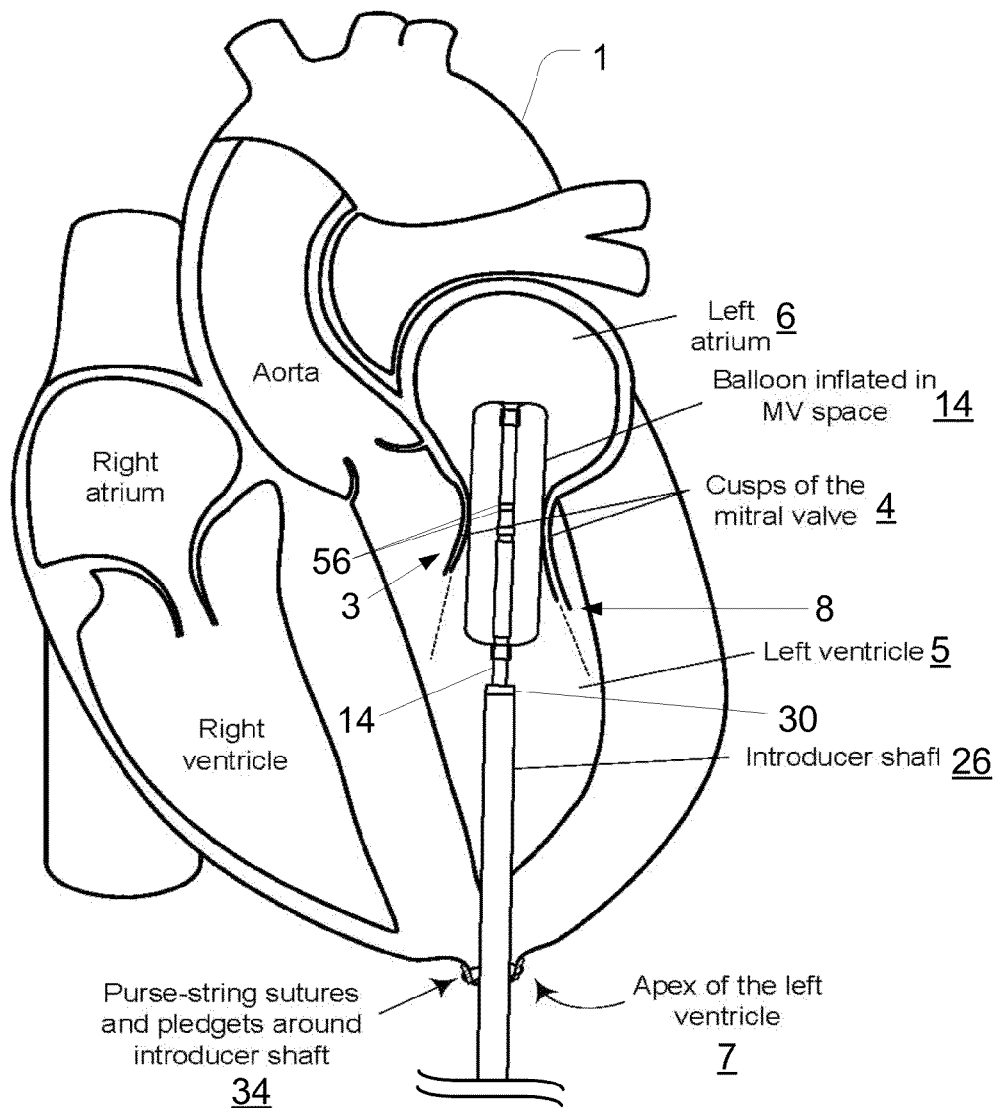


FIG. 14

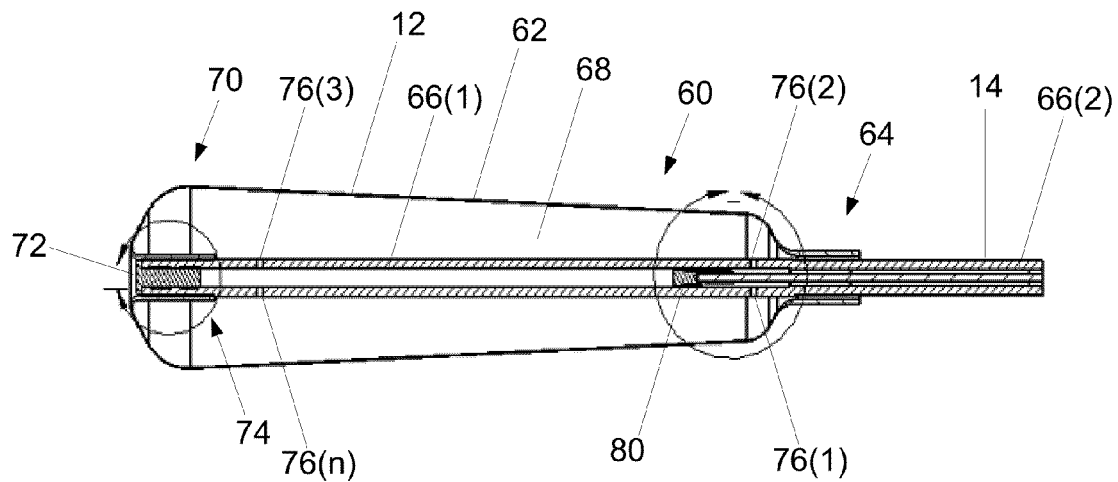


FIG. 15

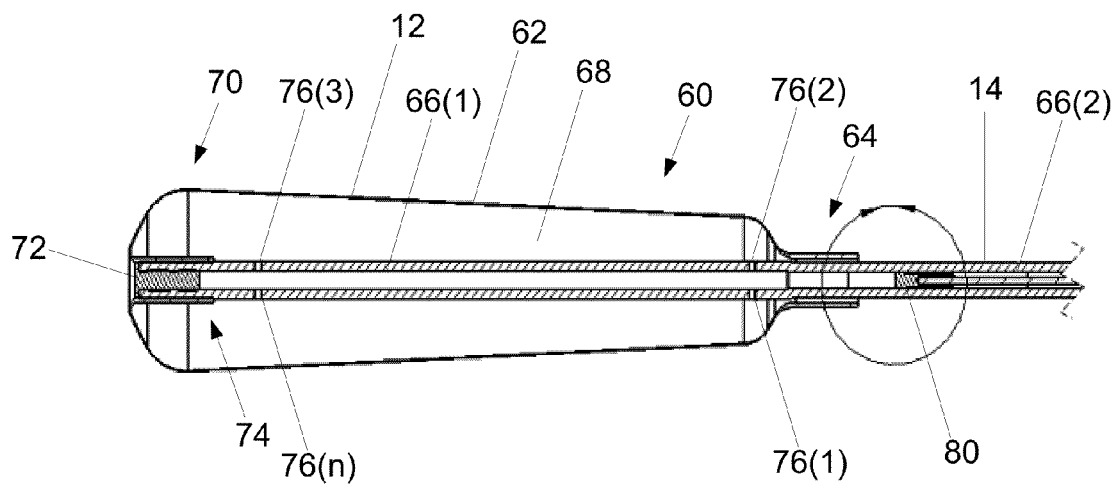


FIG. 16

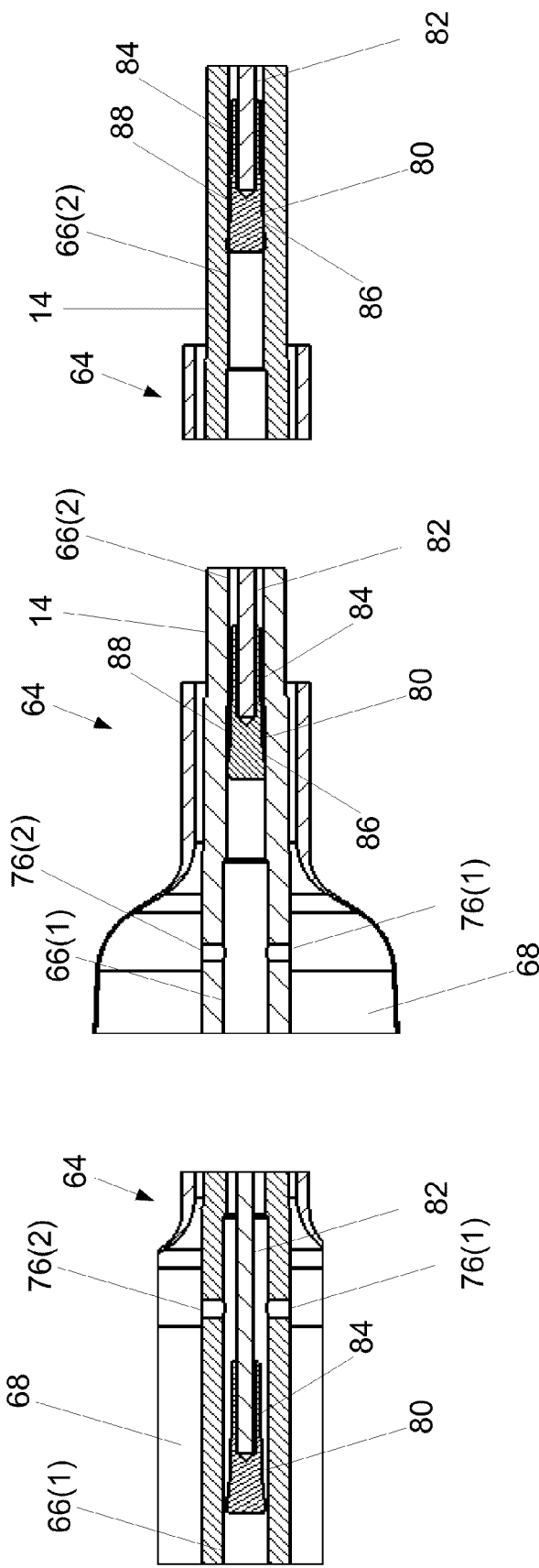


FIG. 18

FIG. 19

FIG. 17



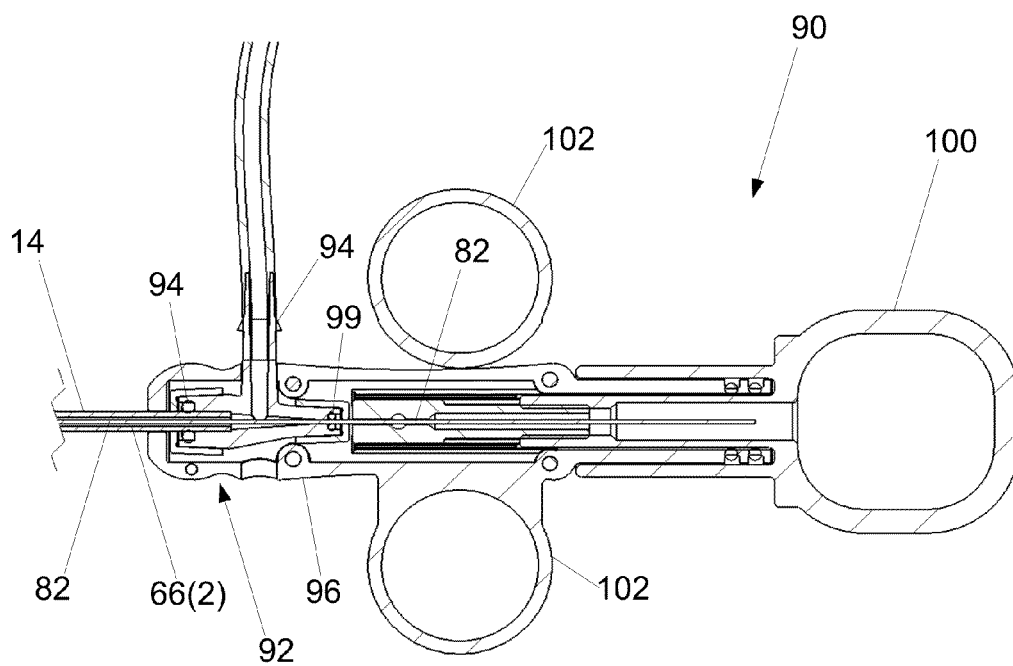


FIG. 20

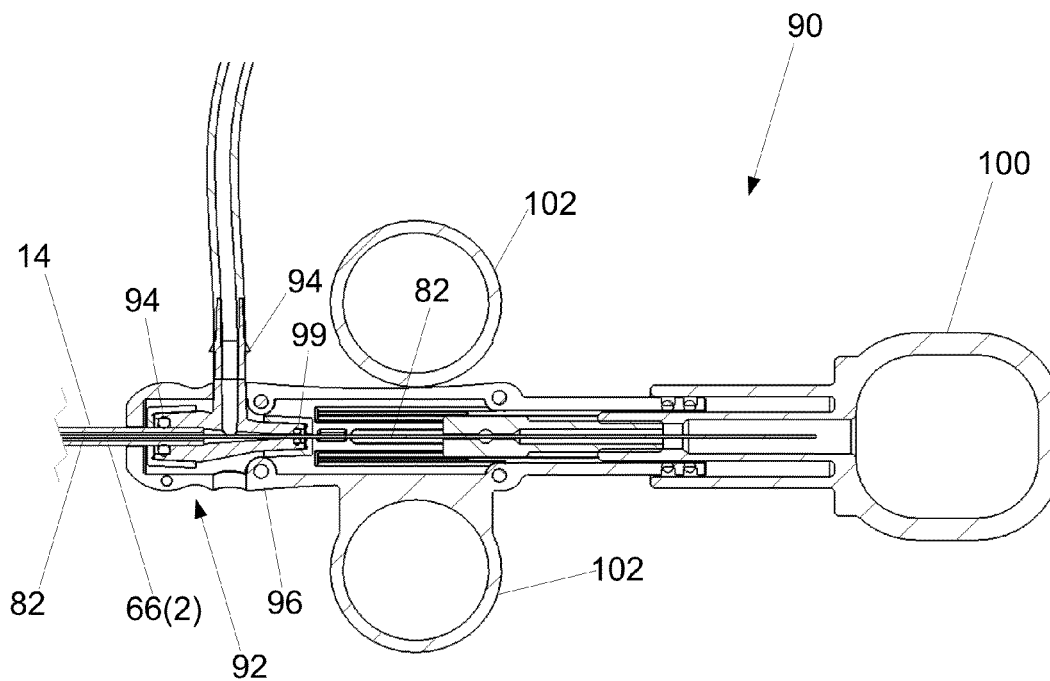


FIG. 21

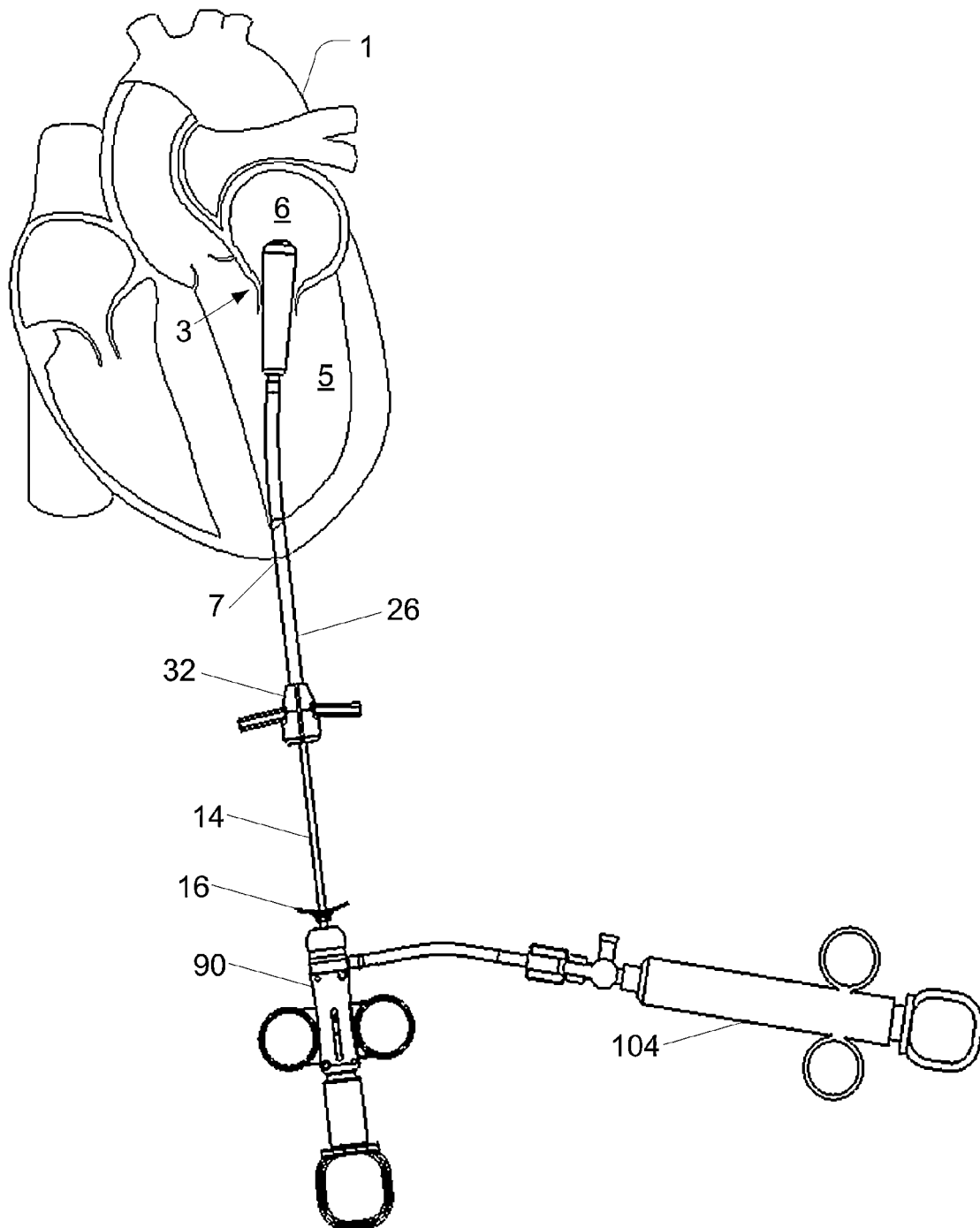


FIG. 22

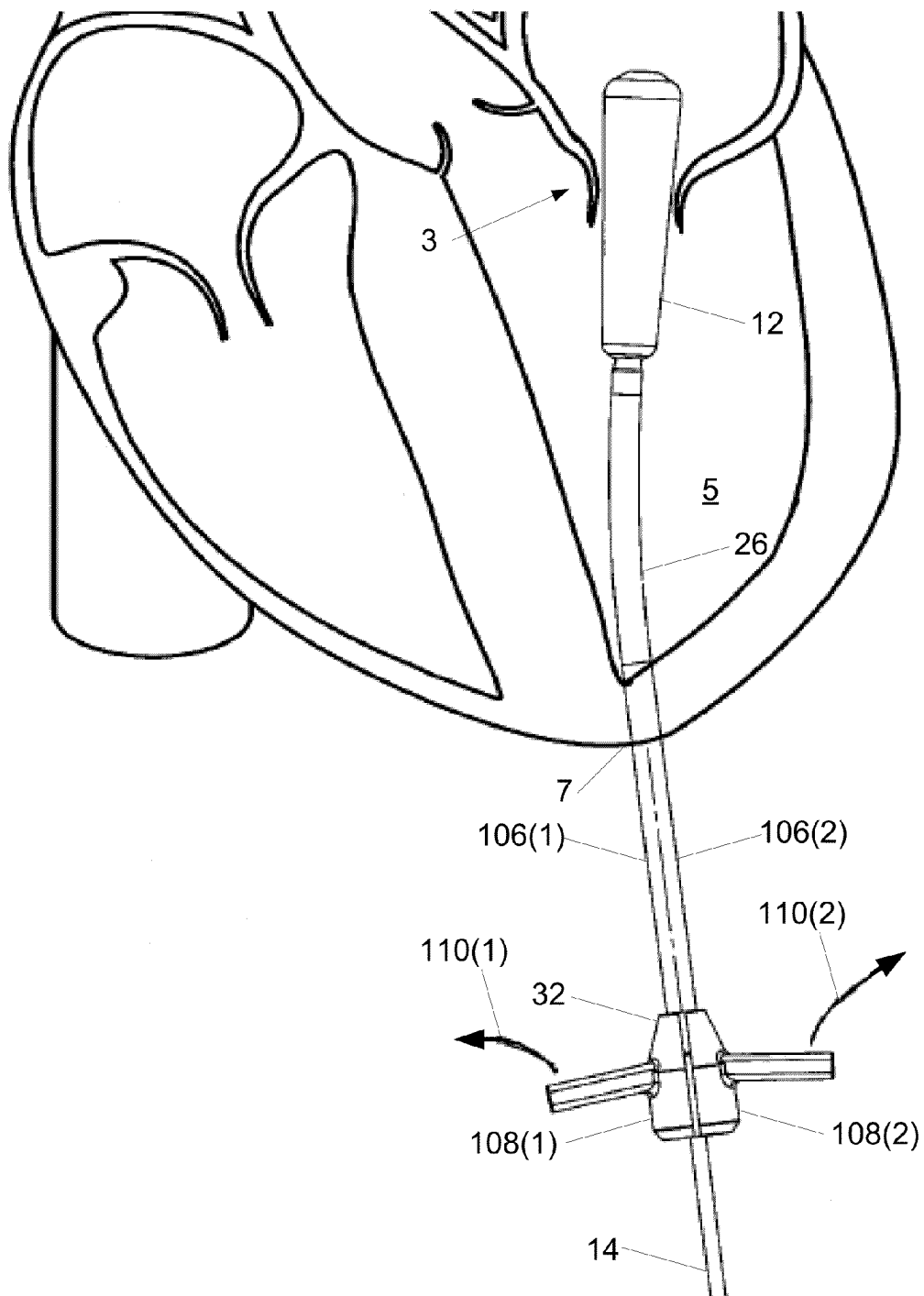


FIG. 23

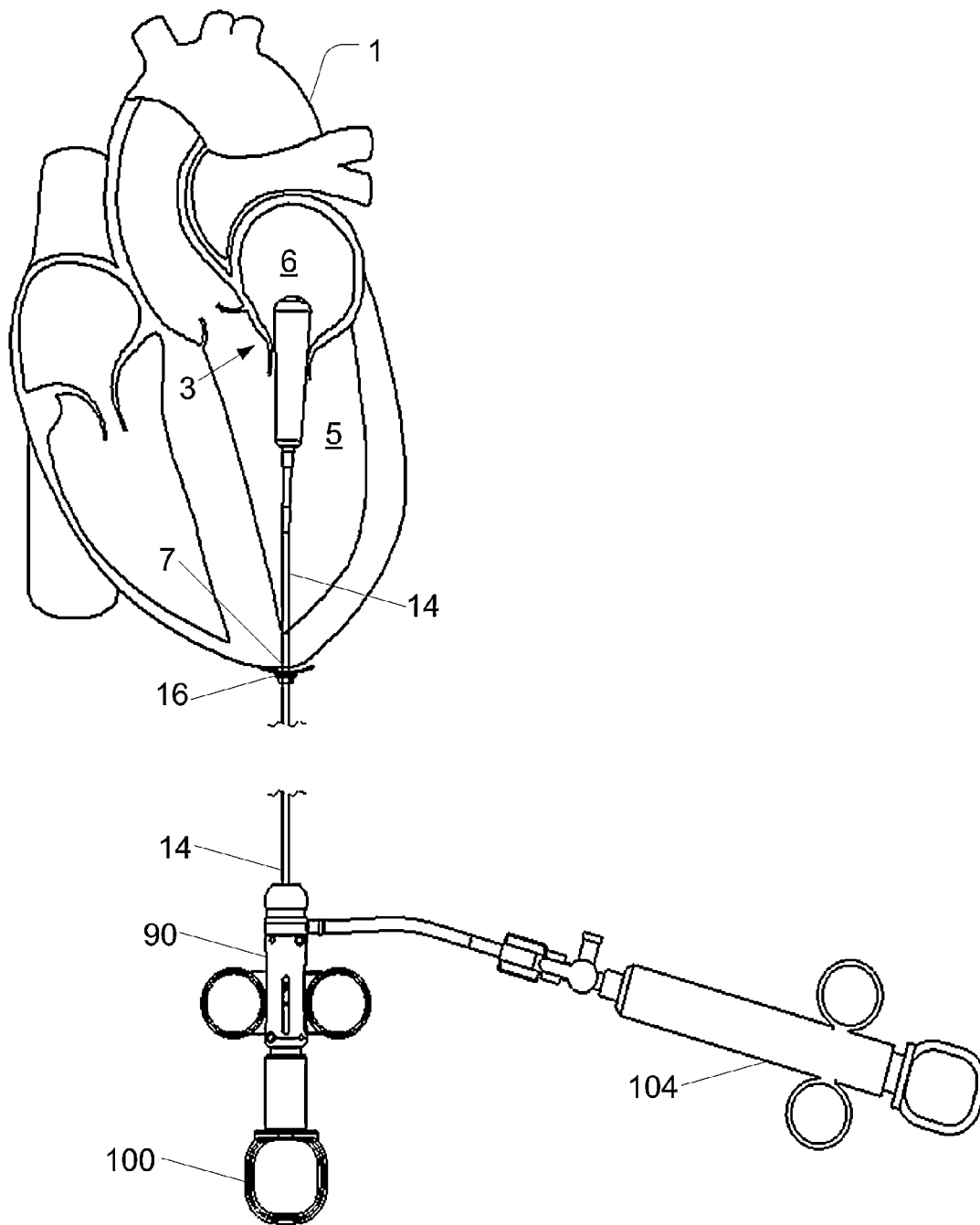


FIG. 24

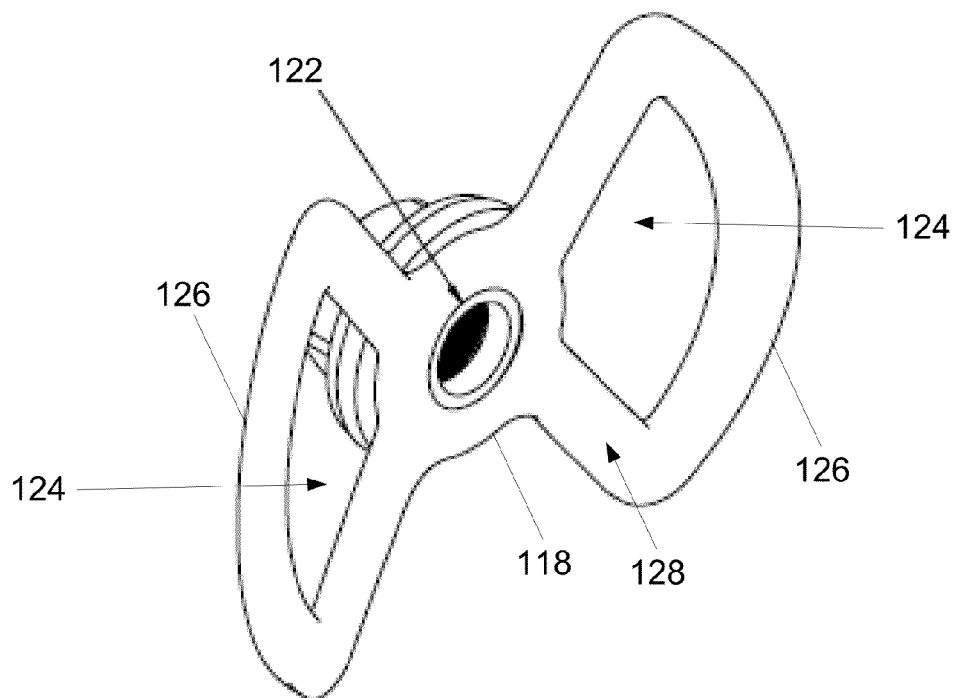


FIG. 25

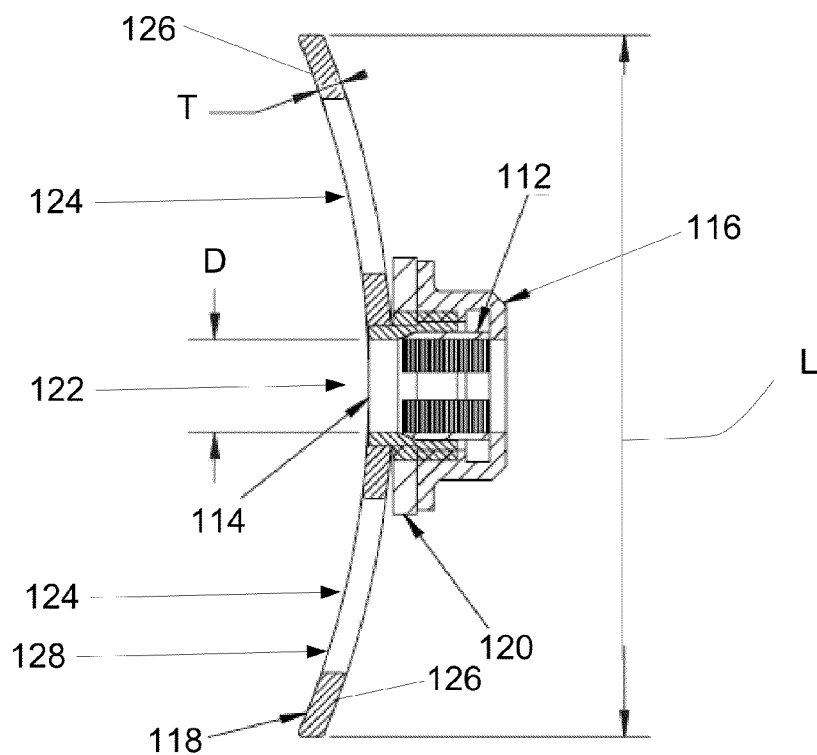


FIG. 26

SECTION B-B

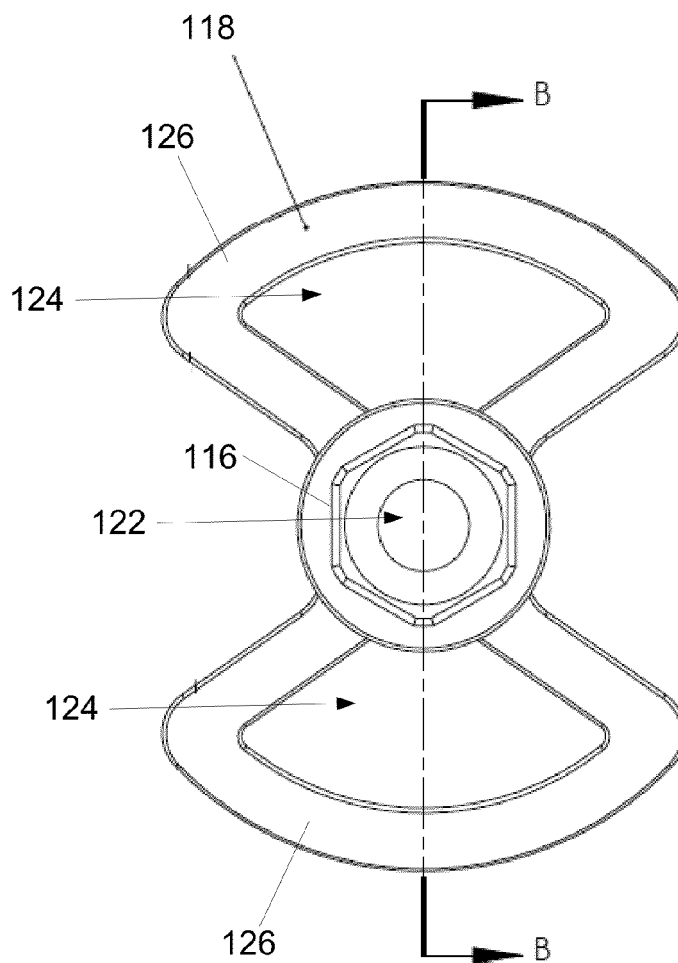


FIG. 27

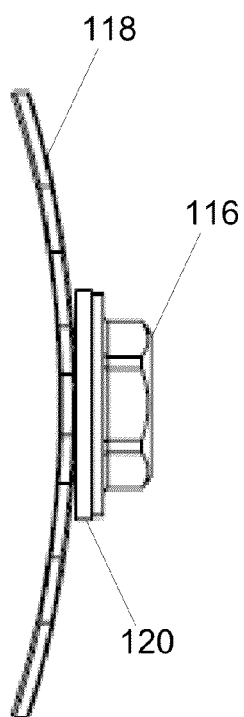


FIG. 28

1

## TRANS-APICAL IMPLANT SYSTEMS, IMPLANTS AND METHODS

### FIELD

The present disclosure relates to the repair and/or correction of dysfunctional heart valves, and more particularly pertains to heart valve implants and systems and methods for delivery and implementation of the same.

### BACKGROUND

A human heart has four chambers, the left and right atrium and the left and right ventricles. The chambers of the heart alternately expand and contract to pump blood through the vessels of the body. The cycle of the heart includes the simultaneous contraction of the left and right atria, passing blood from the atria to the left and right ventricles. The left and right ventricles then simultaneously contract forcing blood from the heart and through the vessels of the body. In addition to the four chambers, the heart also includes a check valve at the upstream end of each chamber to ensure that blood flows in the correct direction through the body as the heart chambers expand and contract. These valves may become damaged, or otherwise fail to function properly, resulting in their inability to properly close when the downstream chamber contracts. Failure of the valves to properly close may allow blood to flow backward through the valve resulting in decreased blood flow and lower blood pressure.

Mitral regurgitation is a common variety of heart valve dysfunction or insufficiency. Mitral regurgitation occurs when the mitral valve separating the left coronary atrium and the left ventricle fails to properly close. As a result, upon contraction of the left ventricle blood may leak or flow from the left ventricle back into the left atrium, rather than being forced through the aorta. Any disorder that weakens or damages the mitral valve can prevent it from closing properly, thereby causing leakage or regurgitation. Mitral regurgitation is considered to be chronic when the condition persists rather than occurring for only a short period of time.

Regardless of the cause, mitral regurgitation may result in a decrease in blood flow through the body (cardiac output). Correction of mitral regurgitation typically requires surgical intervention. Surgical valve repair or replacement is carried out as an open heart procedure. The repair or replacement surgery may last in the range of about three to five hours, and is carried out with the patient under general anesthesia. The nature of the surgical procedure requires the patient to be placed on a heart-lung machine. Because of the severity/complexity/danger associated with open heart surgical procedures, corrective surgery for mitral regurgitation is typically not recommended until the patient's ejection fraction drops below 60% and/or the left ventricle is larger than 45 mm at rest.

In some instances, patients who are suffering from mitral regurgitation are also in need of an aortic valve replacement. Studies have shown, for example, that about 30% of patients who are in need of an aortic valve replacement also have moderate to severe mitral regurgitation. Typically, these patients only receive an aortic valve replacement, and the mitral regurgitation is not treated. One method of aortic valve replacement includes trans-apical aortic valve. A trans-apical aortic valve replacement may be delivered via a trans-apical approach which utilizes a short incision (e.g., 3-4 inch long) between two ribs to gain access to the apex of the left ventricle. This is sometimes referred to as a "mini-thoracotomy," and is much less invasive than the traditional method of get-

2

ting access to the heart; a median sternotomy which involves cracking the sternal bone in the middle and spreading the chest wide open.

Another common heart condition includes coronary artery disease which may be treated by coronary artery bypass graft (CABG) surgery via a mini-thoracotomy. Sometimes such patients can also benefit from concomitant mitral repair. In fact, sometimes the patient has mitral regurgitation because of the coronary blockage, and CABG alone is not enough to treat the mitral regurgitation.

Accordingly, there exists a need to treat mitral regurgitation, particularly using a trans-apical approach.

### BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantage of the claimed subject matter will be apparent from the following description of embodiments consistent therewith, which description should be considered in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of one embodiment of a mitral valve implant consistent with the present disclosure;

FIG. 2 generally illustrates a needle being inserted through the apex into the left ventricle;

FIG. 3 generally illustrates a guidewire being inserted through the needle into the left ventricle;

FIG. 4 generally illustrates the needle removed and the guidewire in the left ventricle;

FIG. 5 generally illustrates one embodiment of an introducer and dilator being inserted into the left ventricle;

FIG. 6 generally illustrates purse-string sutures and pledgets secured around the introducer;

FIG. 7 generally illustrates the guidewire removed from the introducer;

FIG. 8 generally illustrates one embodiment of a messenger balloon partially beyond the tip of the introducer;

FIG. 9 generally illustrates the messenger balloon inflated at the tip of the introducer;

FIG. 10 generally illustrates the inflated messenger balloon being advanced through the mitral valve;

FIG. 11 generally illustrates the inflated messenger balloon in the left atrium

FIG. 12 generally illustrates the implant being loaded into the introducer;

FIG. 13 generally illustrates the implant in the left atrium;

FIG. 14 generally illustrates the implant in the mitral valve;

FIG. 15 generally illustrates the implant in a retracted position prior to filling;

FIG. 16 generally illustrates the implant in an expanded position after filling;

FIG. 17 generally illustrates one embodiment of a spacer valve assembly in a retracted position prior to filling;

FIG. 18 generally illustrates the spacer valve assembly in an expanded position after filling;

FIG. 19 generally illustrates the spacer valve assembly in an intermediate position;

FIG. 20 generally illustrates one embodiment of an inflation handle assembly in a retracted position prior to filling;

FIG. 21 generally illustrates the inflation handle assembly in an expanded position after filling;

FIG. 22 generally illustrates the implant in the mitral valve, the inflation handle assembly, and a splitter;

FIG. 23 generally illustrates splitting the introducer after the implant has been verified in the mitral valve;

FIG. 24 generally illustrates implant in the mitral valve with the anchor assembly advanced to the apex;

FIGS. 25-28 generally illustrate various views of one embodiment of the anchor assembly.

By way of an overview, a perspective view of one embodiment of a trans-apical mitral valve implant **10** is illustrated within the heart **1** is generally illustrated in FIG. 1. The trans-apical mitral valve implant **10** (hereinafter referred to simply as the implant **10** and/or mitral valve implant **10**) includes a spacer **12**, a shaft **14**, and optionally an anchor assembly **16**. In general, the mitral valve implant **10** is delivered within the heart **1** and anchored to the native coronary tissue **2** as generally illustrated in FIG. 1 such that at least a portion of the spacer **12** is disposed proximate a mitral valve **3** and the mitral valve implant **10** may interact and/or cooperate with at least a portion of the native mitral valve **3** to reduce and/or eliminate excessive regurgitation. For example, at least a portion of one or more cusps **4** of the heart **1** valve may interact with, engage, and/or seal against at least a portion of the heart valve implant **10** (for example, but not limited to, the spacer **12**) when the mitral valve **3** is in a closed condition. The interaction, engagement and/or sealing between at least a portion of at least one cusp **4** and at least a portion of the heart valve implant **10** may reduce and/or eliminate regurgitation in a heart valve **3**, for example, providing insufficient sealing, including only a single cusp **4**, e.g., following removal of a diseased and/or damaged cusp **4**, and/or having a ruptured cordae. A heart valve implant **10** consistent with the present disclosure may be used in connection with various additional and/or alternative defects and/or deficiencies.

As discussed in greater detail herein, the mitral valve implant **10** is delivered to the mitral valve **3** within the left ventricle **5** and/or left atrium **6** by way of a trans-apical approach. A short incision (e.g., 3-4 inch long) between two ribs is formed to gain access to the apex **8** of the left ventricle **5**. An incision is made through the apex **8** to gain access to the left ventricle **5**. The mitral valve implant **10** is then introduced into the mitral valve **3**, the spacer **12** is expanded, and the anchor is secured to the native coronary tissue **2** of the heart **1**, for example, on the outside of the heart **1** proximate to the apex **7**.

The mitral valve implant **10** provides numerous benefits. For example, the mitral valve implant **10** may be installed to reduce/prevent mitral regurgitation on a beating heart (i.e., without removing the patient's heart and without cardiopulmonary bypass (CPB) surgery). The trans-apical approach is therefore less invasive compared to a median sternotomy. Additionally, as noted above, many patients who suffer from mitral regurgitation also suffer from other conditions which necessitate trans-apical surgery. As such, the mitral valve implant **10** according to the present invention allows for the treatment of mitral regurgitation without requiring significant invasive surgery (e.g., the mitral valve implant **10** may be implanted while the patient is already undergoing trans-apical surgery to address other medical conditions).

With reference to FIG. 2, the trans-apical system and method includes gaining access to the left ventricle **5**. For example, a hollow needle **20** (which may be coupled to a needle hub **22**) is inserted through the apex **7** of the left ventricle **5** and into the left ventricle **5**. Once access has been achieved to the left ventricle **5**, a guide wire **24** is introduced through the lumen of the hollow needle **20** into the left ventricle **5** as generally illustrated in FIG. 3. The guide wire **24** may include a 1/32" wire and may optionally form a curved, pig-tail-like shape after the guide wire **24** exits the lumen of the hollow needle **20** in the left ventricle **5**.

With the guide wire **24** in the left ventricle **5**, the hollow needle **20** is removed from heart **1**, leaving the guide wire **24**

remaining in the left ventricle **5** as generally illustrated in FIG. 4. The guide wire **24** may be used as a pathway for advancing other instruments and devices into the heart **1**. For example, an introducer **26** and/or dilator **28** may be advanced along the guide wire **24** into the left ventricle **5** as generally illustrated in FIG. 5.

The distal end **30** of the shaft of the introducer **26** may be beveled to aid in passing the introducer **26** through incision in the apex **7**. The introducer **26** may also feature a predefined bend **27**. The predefined bend **27** is formed in the introducer **26** during the manufacturing of the introducer **26** and is configured to facilitate alignment of the distal end **30** of the introducer **26** with the mitral valve **3**. Without the bend **27** (e.g., if the introducer was just linear), it would be very difficult to align the tip **30** of the introducer **26** with the mitral valve **3** and between the two papillary muscles, and into the outflow tract of the mitral valve **3**. While the bend/curvature **27** does not appear to be perfectly aligned with the mitral valve **3**, this is due (in part) to the three-dimensional path which is not readily shown in a two-dimensional drawings. The bend **27** may be disposed at an angle of approximately 20-40 degrees, for example 30 degrees, from the longitudinal axis of the main portion of the introducer **26** extending outwardly from the incision in the apex **7**.

The introducer **26** may optionally include a splitter (also referred to as the introducer hub) **32** configured to longitudinally split the shaft of the introducer **26** such that the introducer **26** forms a split catheter which can be easily removed while allowing an object within the lumen of the introducer **26** (e.g., the guidewire **24** and/or a portion of the implant **10**) to remain within the lumen of the introducer **26**. The splitter **32** may include a seal configured to allow another device and/or lumen to be selectively and removably sealed and/or advanced through the to the splitter **32** into the lumen of the introducer **26**.

For example, the splitter **32** (introducer hub) may include at least two parts, namely, an outer shell made of a polymer that has been molded in such a way as to provide a preferential and controlled break-away seam, and the inner seal made of silicone rubber also with a molded break-away seam. The outer shell and silicone seal are mechanically connected so that the break-away seams are both positioned along the same axis as the shaft/lumen of the introducer **26**. The splitter **32** (introducer hub) is mechanically connected to the proximal end of the introducer's tubular shaft. When the "handles" of the outer shell of the splitter **32** (introducer hub) are actuated in opposite directions, with sufficient force, rotating away from the axis of the introducer **26** toward the distal end of the introducer **26**, the preferential break-away seams of the outer shell and of the inner seal of the splitter **32** (introducer hub) permanently separate and propagate a tear in the wall of the tube of the introducer **26**. Continuing to further separate the handles of the splitter **32** (introducer hub) in turn continues to advance the tear in the tube of the introducer **26**. The user continues to separate the handles, tearing the tube until the tear reached the distal end of the tube and completes the axial separation of the introducer **26**.

Once the introducer **26** has been advanced into the left ventricle **5** through the incision in the apex **7**, one or more purse-string sutures and/or pledgets **34** may be secured around the shaft of the introducer **26** and the incision as generally illustrated in FIG. 6. The purse-string sutures and/or pledgets **34** are configured to apply a radially compressive force against the shaft of the introducer **26** during the procedures, thereby minimizing the potential for accidentally tearing the heart tissue proximate to the incision and also minimizing blood loss during the procedure. For example, one or



5

more heavy-gauge sutures may be passed around the shaft of the introducer **26** in a continuous loop, so that when it is all the way around, the suture can be pulled tight like a noose or purse-string to hold the surrounding tissue tightly around the introducer **26**. To prevent the suture from tearing through the tissue, each time the suture passes through tissue, the suture also passes through a small pledget of woven polyester fabric. Optionally, two purse-strings (each with four pledgets) may be used to secure the introducer **26** to the left ventricle wall.

One embodiment of a dilator **28** may include define at least one lumen configured to receive at least a portion of the delivery guide wire **24**. For example, the lumen may have an internal diameter of approximately 0.038". The dilator **28** may also comprise a shaft including a tapered tip region **46**. The tapered distal tip **46** may be provided to facilitate advancing the tip **46** into the puncture site in the apex **7** as the dilator **28** is introduced over the delivery guide wire **24**. The shaft may comprise a plurality of segments or portions having different stiffness or hardness to produce the desired overall curvature. The shaft may be formed from one or more suitable polymers such as, but not limited to, a polyether block amide. The shaft may have a constant inner and/or outer diameter and may be made from different materials to provide the various stiffness or hardness. Alternatively, or in addition, the shaft may have different inner and/or outer diameters and may be made from one or more materials. For example, the various stiffness or hardness of the shaft may be provided by varying the thickness of the shaft at the different segments or portions. The different hardness of the segments may provide differing degrees of bending stiffness to the dilator **28** which may facilitate advancing the dilator **28** into and/or out of the left ventricle **3**.

Once the introducer **26** is positioned in the left ventricle **5**, the guidewire **24** may be removed, leaving the introducer **26** and dilator **28** in the left ventricle **5** as generally illustrated in FIG. 7. Because of the predetermined bend **27**, the distal end **30** of the introducer **26** and/or dilator **28** is generally aligned with the mitral valve **3**. A deflated messenger balloon **48** may be advanced through the lumen of the introducer **26** and/or dilator **28** until at least a portion of the deflated messenger balloon **48** exits the distal end **30** of the introducer **26** and/or dilator **28** as generally illustrated in FIG. 8 (the dilator **28** is shown retracted into the introducer **26** for clarity). A shaft **50** of the messenger balloon **48** may include indicia **51** for indicating the position of the messenger balloon **48** relative to the introducer **26**. For example, when the indicia (which may include the proximal end of a fabric covering the shaft **50**) is aligned with and/or protrudes a few millimeters from the splitter **32**, about 1 cm of the messenger balloon **48** is protruding from the end **30** of the introducer **26**.

The messenger balloon **48**, when expanded, is configured to facilitate advancement of the introducer **26** and/or dilator **28** through the mitral valve **3** without damaging the mitral valve **3** or becoming entangled in the mitral valve **3** (for example, the cusps **4**, the chordae and/or papillary muscles **8** of the mitral valve **3**). The messenger balloon **48** may be disposed proximate the distal end region of a shaft **50** and may be fluidly coupled through the shaft **50** to an expansion medium such as, but not limited to, a gas and/or liquid which may expand and/or enlarge the messenger balloon **48** from the deflated or retracted position as generally illustrated in FIG. 8 to the inflated or expanded position as generally illustrated in FIG. 9 (note, that the messenger balloon **48** is only partially extending from the introducer **26**). The messenger balloon **48** forms a soft tip which serves as an atraumatic "bumper" tip to minimize the risk of damaging or even irritating the delicate lining (endocardium) of the left ventricle **5**.

6

To much contact with the left ventricle **5** can cause a dangerous arrhythmia. According to at least one embodiment, the expansion medium may include carbon dioxide CO<sub>2</sub> gas and/or saline. Optionally, contrast media may be introduced into the messenger balloon **48** to allow the messenger balloon **48** to be more easily visually located using fluoroscopy or the like. The contrast media may coat the inside surface of the messenger balloon **48**.

The messenger balloon **48** may include a resiliently expandable/collapsible material such as, but not limited to, silicone, Yulex™ or the like which may be selectively collapsed and/or expanded. The messenger balloon **48** may be bonded to the shaft **50** and may include one or more passageways, apertures or lumens to allow the expansion medium to expand/collapse the messenger balloon **48**. The diameter of the messenger balloon **48** should be small enough in the first or retracted/collapsed position to be advanced over the delivery guide wire **24** through the introducer **26** and/or dilator **28** to the left ventricle **5** and large enough when in the second or expanded/inflected position to be advanced through the cusps **4** and chordae **8** of the mitral valve **3** to reduce the potential of damaging the heart **1** and/or getting entangled within the mitral valve **3**. For example, the shaft **50** may have an outer diameter of approximately 0.062" (e.g., a 5 Fr). The messenger balloon **48** may diameter of approximately 0.100" in the first position and a diameter of approximately 15 mm to approximately 20 mm cm in the second position with a length of approximately 8 to approximately 10 mm.

The messenger balloon **48** is advanced towards the mitral valve **3** as generally illustrated in FIG. 10. As can be seen, the bend **27** in the introducer **26** helps to get the introducer **26** correctly orientated spatially, to find the space between the two papillary muscles and avoid the chordae. As noted above, the limitations of the two-dimensional figures do not completely convey the advantage of the bend **27**. With the messenger balloon **48** proximate to the mitral valve **3**, the messenger balloon **48** may be advanced through the mitral valve **3**. The backflow from the left ventricle **5** through the mitral valve **3** into the left atrium **6** (even for a normal mitral valve) helps "pull" the inflated messenger balloon **48** into the mitral space such that the messenger balloon **48** may ultimately be advanced into the left atrium **6** as generally illustrated in FIG. 11. The introducer **26** and the dilator **28** may then be advanced over the shaft **50** of the messenger balloon **48** into the left atrium **6**.

Once the introducer **26** has been advanced through the mitral valve **3** into the left atrium **6**, the dilator **28**, guide wire **24**, and the messenger balloon **48** may be removed from the introducer **26** and the retracted/deflated implant **10** may be loaded into the introducer **26** (for example, through the splitter **32**) as generally illustrated in FIG. 12. Prior to loading the implant **10** into the introducer **26**, the implant **10** may be de-aired. If entrapped air from the implant **10** is allowed to be introduced into the patient's cardiovascular system, the air may travel to the patient's brain or other parts of the patient's body where it may cause serious bodily harm and/or death (for example, due to blood clotting or the like). To de-air the implant **10**, a fluid (such as, but not limited to, a saline solution or the like) may be injected through the inflation lumen **66** into the spacer cavity **68** to flush away and/or remove any entrapped air before the implant **10** is inserted into the introducer **26**.

As note previously, the implant **10** includes an expandable spacer **12**, a shaft **14**, and an anchor assembly **16**. When the implant **10** is loaded into the introducer **26**, the shaft **14** may have a length substantially longer than the length of the shaft **14** when the implant **10** is secured to the heart **1** (e.g., as

7

shown in FIG. 1). For example, the shaft 14 may be long enough to allow the surgeon to manipulate the implant 10 from outside of the patient's body while the implant 10 is disposed within the left atrium 6/mitral valve 3. The shaft 14 may include generally flexible tubing such as, but not limited to, a poly(tetrafluoroethylene) (PTFE) tube defining an lumen. Optionally, the exterior surface of the shaft 14 may include a fabric sheath or the like configured to prevent blood clots from becoming dislodged off the shaft 14. The shaft 14 may also optionally include one or more stiffeners (not shown) to provide the necessary amount of rigidity to the shaft 14 such that the shaft 14 is able to maintain the position of the spacer 12 with respect to the mitral valve 3 when installed. The stiffener may include, for example, braided mesh or the like.

According to one embodiment, the shaft 14 is secured to a handle assembly 54 and the anchor assembly 16 may be disposed proximate to the handle assembly 54. The handle assembly 54 may be used to advance the implant 10 through the introducer 26 until at least a portion of the implant 10 (e.g., the retracted/deflated spacer 12) protrudes beyond the distal end 30 of the introducer 26 in the left atrium 6 as generally illustrated in FIG. 13. Once a portion of the spacer 12 protrudes beyond the distal end 30 of the introducer 26, the introducer 26 may be retracted slightly to allow the rest of the spacer 12 to protrude beyond the distal end 30. The spacer 12 may also be inflated using the handle assembly 54 and pulled back from the left atrium 6 and into the annulus of the mitral valve 3 as generally illustrated in FIG. 14. The position of the spacer 12 within the annulus of the mitral valve may be determined using one or more markers 56 (e.g., radio-opaque markers which may be visible under fluoroscopy). The distal end 30 of the introducer 26 is now disposed in the left ventricle 5. Contrast medium can be injected into the introducer 26, to the left ventricle 5 to verify if the mitral regurgitation has been significantly reduced by the action of the spacer 12 engaging with the cusps 4 of the mitral valve 3.

Turning now to FIGS. 15 and 16, the spacer valve assembly 60 of the implant 10 is generally illustrated in a retracted position (FIG. 15) in which the spacer 12 is ready to be expanded (i.e., ready to receive an expansion medium) and in an expanded position (FIG. 16) in which the spacer 12 has been expanded and sealed. The spacer valve assembly 60 allows the spacer 12 to be selectively expanded and/or deflated to desired pressure or stiffness. The spacer 12 includes a resilient flexible wall 62 formed from a biologically acceptable material, for example, Elast-Eon™ material or the like.

A first (proximal) end 64 of the wall 62 is coupled, mounted, or otherwise secured to a portion of the shaft 14. The spacer 12 may include a first inflation lumen 66(1), which may extend substantially along substantially the entire longitudinal axis of the spacer 12 or only a portion thereof. The first inflation lumen 66(1) is fluidly coupled to a second inflation lumen 66(2) associated with the shaft 14 and is configured to allow an expansion medium (such as, but not limited to, saline or the like) into a spacer cavity 68 from the handle assembly 54 (the handle assembly 54 may be seen, e.g., in FIG. 12). The first inflation lumen 66(1) may be a component of the spacer 12 and/or may include an extension of the shaft 14 (e.g., the first and second inflation lumens 66(1), 66(2) may be parts of the same lumen).

The spacer cavity 68 is defined by the first inflation lumen 66(1) and the wall 62. The second (distal) end 70 of the spacer 12 includes an end plug 72 configured to seal the distal end 74 of the second portion of the first inflation lumen 66(1) to the wall 62. The first inflation lumen 66(1) also includes a plurality of apertures 76(1)-(n). The apertures 76(1)-(n) may be

8

disposed along the length of the first inflation lumen 66(1) and are configured to allow the expansion medium to flow from the first inflation lumen 66(1) into the spacer cavity 62. The first inflation lumen 66(1) may include a first set of apertures (e.g., apertures 76(1), 76(2)) which are disposed proximate to the first end 62 of the spacer 12 and/or a second set of apertures (e.g., apertures 76(3), 76(n)) which are disposed proximate to the second end 70 of the spacer 12. The use of two sets of apertures allows for more even inflation of the spacer cavity 68.

As noted herein, the spacer valve assembly 60 is configured to allow the surgeon to selectively expand/retract the spacer 12, and more specifically, the spacer cavity 68. The spacer valve assembly 60 may feature a plunger 80 disposed within first and/or second inflation lumens 66(1), 66(2) which is configured to selectively seal the first inflation lumen 66(1) and/or the apertures 76(1)-(n) and selectively allow the expansion medium to flow into and/or out of the spacer cavity 68.

With reference to FIGS. 17-19, various positions of the plunger 80 within the first and/or second inflation lumens 66(1), 66(2) are generally illustrated. In particular, FIG. 17 illustrates the plunger 80 in the retracted position ready to be expanded corresponding to FIG. 15. FIG. 18 illustrates the plunger 80 in the expanded, sealed position corresponding to FIG. 16. FIG. 19 illustrates the plunger 80 in an optional, intermediate position in which the spacer cavity 68 is selectively, removably sealed such that the expansion of the spacer cavity 68 within the mitral valve 3 can be verified. The intermediate position allows the surgeon to selectively seal and unseal the plunger 80 such that the surgeon can selectively expand and/or retract the spacer cavity 68 based on the performance of the implant 10 within the mitral valve 3.

The plunger 80 is coupled to a plunger wire 82. The plunger wire 82 extends through the inflation lumens 66(1), 66(2) of the spacer 12 and/or the shaft 14 and may be coupled to an inflation handle assembly as described herein. The plunger wire 82 allows the surgeon to move the plunger within the first and/or second inflation lumens 66(1), 66(2) into any of the inflation/sealing positions. The plunger wire 82 may be releasably coupled to the plunger wire 82, for example, using a threaded connection 84 or the like.

With reference to FIG. 17, the plunger 80 is in the expansion position ready to be expanded and the apertures 76(1)-(n) are fluidly coupled to the first and second inflation lumens 66(1), 66(2). The plunger 80 may be disposed within the first inflation lumen 66(1) between the first set of apertures 76(1), 76(2) and the second set of apertures 76(3), 76(n). Because the first set of apertures 76(1), 76(2) are upstream of the plunger 80, the first set of apertures 76(1), 76(2) are fluidly coupled to the inflation lumen 66(1). The first inflation lumen 66(1) may have a tapered internal diameter which expands along the longitudinal axis of the spacer 12 from first or proximal end 64 towards the second or distal end 70 of the spacer 12. At least a portion of the cross-section (e.g., the diameter) of the first inflation lumen 66(1) is larger than the cross-section (e.g., diameter) of the plunger 80 such that fluid can flow past the plunger 80, thereby fluidly coupling the second set of apertures 76(3), 76(n) to the inflation lumen 66(1).

Turning now to FIG. 18, the plunger 80 is in the retracted/sealed position in which the apertures 76(1)-(n) are fluidly sealed from the first and second inflation lumens 66(1), 66(2). The plunger 80 may be disposed within and sealed with the first or second inflation lumen 66(1), 66(2) upstream of first and second sets of apertures 76(1)-(n). As such, no expansion medium can flow into or out of the apertures 76(1)-(n) and the

spacer cavity 68 is sealed. For the sake of clarity, the plunger 80 will be described as sealing with the second inflation lumen 66(2), however, it should be appreciated that the plunger 80 may seal with either the first and/or the inflation lumens 66(1), 66(2).

The plunger 80 may have a tapered 84 (e.g., a generally cylindrical taper) configured to create a frictional connection (e.g., a Morse taper or the like) with the corresponding taper 86 (e.g., a generally cylindrical taper) of the second inflation lumen 66(2) to seal the second inflation lumen 66(2), and ultimately the spacer cavity 68. The plunger 80 may also form a threaded connection with the second inflation lumen 66(2) to seal the second inflation lumen 66(2), and ultimately the spacer cavity 68. Alternative embodiments of sealing the plunger 80 with the second inflation lumen 66(2) are also possible.

FIG. 19 illustrates the plunger 80 in an optional, intermediate position. When the plunger 80 is in the intermediate position, the surgeon may selectively seal and unseal the spacer cavity 68 to allow the spacer 12 to be expanded further or retracted. The intermediate position may be used when verifying the performance of the spacer 12 within the mitral valve 3. To seal the spacer cavity 68, the plunger 80 is urged distally such that a portion of the plunger 80 seals against the tapered inflation lumen 66(1), 66(2) at a position which is upstream of the apertures 76(1)-(n). To unseal the spacer cavity 68 (e.g., in the event that the surgeon wants to release some of the expansion medium from the spacer cavity 68 to reduce the overall size of the spacer 12), the surgeon urges the plunger 80 proximally. The increasing taper in of the inflation lumen 66(1), 66(2) allows for the expansion medium to flow past the plunger 80 thereby fluidly coupling the apertures 76(1)-(n) to the inflation lumen 66(1), 66(2). In this manner, the surgeon can easily adjust the size of the spacer 12 based on the performance of the implant 10 within the mitral valve 3.

It should be appreciated that the orientations of taper 86 of the plunger 80 and the taper 88 of the inflation lumen 66 may be switched. Switching the orientations of the tapers 86, 88 would result in urging the plunger 80 in the opposite directions to seal and unseal the spacer cavity 68.

Turning now to FIGS. 20 and 21, one embodiment of an inflation handle assembly 90 is generally illustrated. A proximal end 92 of the shaft 14 may be secured (either permanently or releasably secured) to a portion of the inflation handle assembly 90. For example, the shaft 14 may be hermetically sealed and coupled to inflation handle assembly 90 using one or more seals 94. The body 96 of the inflation handle assembly 90 includes an inflation port 98 which is fluidly coupled to the inflation lumen 66(2) of the shaft 14. The inflation port 98 is configured to be secured to an inflation source (e.g., but not limited to, a plunger/syringe or the like, not shown) for providing the expansion medium to the spacer cavity 68 as described herein.

The plunger wire 82 extends from the inflation lumen 66(2) of the shaft 14 and passes through the body 96 of the inflation handle assembly 90. One or more seals 99 may be provided to seal the body 96 to the plunger wire 82 as the plunger wire 82 passes through the body 96. The proximal end of the plunger wire 82 is optionally secured to a translator 100. The translator 100 (which may include a ring, slide, knob, or the like) may be configured to move with respect to the body 96 to push or pull the plunger wire 82 within the inflation lumens 66(1), 66(2). For example, when the translator 100 is in the position illustrated in FIG. 20, the plunger 80 may be arranged in the inflation position as generally illustrated in FIGS. 15 and 17. When the translator 100 is in the position illustrated in FIG. 21, the plunger 80 may be arranged in the expanded, sealed

position as generally illustrated in FIGS. 16 and 18. When the translator 100 is in a position between FIGS. 20 and 21, the plunger 80 may be arranged in the intermediate position as generally illustrated in FIG. 19.

The inflation handle assembly 90 may optionally include one or more handle features 102 extending from the body 96 that are configured to facilitate handling of the inflation handle assembly 90 with one hand. For example, the inflation handle assembly 90 may include two handle features 102 disposed on generally opposite sides of the body 96, each of which is configured to receive a different one of a user's fingers (for example, the pointer and middle fingers, respectively). The translator 100 may feature a ring configured to receive a user's thumb. With this arrangement, the surgeon may grip the inflation handle assembly 90 with a single hand and translate the translator 100 back and forth to urge the plunger wire 82 (and ultimately the plunger 68) back and forth to selectively seal and unseal the spacer cavity 68. This arrangement allows the surgeon to control the inflation medium source using the surgeon's other hand.

Turning now to FIG. 22, the implant 10 is illustrated with the spacer 12 within the heart 1. The shaft 14 of the implant 10 is disposed within the introducer 26 (e.g., a split catheter) and coupled to the inflation handle assembly 90. The anchor 16 is also shown disposed proximate to the inflation handle assembly 90. The inflation port 98 is fluidly coupled to an expansion medium source 104 (e.g., a plunger/syringe). The surgeon may use the inflation handle assembly 90 to manipulate the implant 10 such that the spacer 12 is disposed within the mitral valve 3. The spacer 12 may also be expanded to the desired size using the inflation handle assembly 90 and the expansion medium source 104. The spacer 12 may be sealed using the inflation handle assembly 90 once the desired size of the spacer 12 is determined.

After the operation of the spacer 12 has been verified and the spacer has been sealed, the introducer 26 may be removed from the shaft 14, for example, as generally illustrated in FIG. 23. For example, the splitter 32 may be used to split the introducer 26 into two or more pieces 106(1), 106(2) along its length, for example, by pulling the two halves 108(1), 108(2) generally in the directions of arrows 110(1), 110(2). As the introducer 26 is split, the introducer 26 may be retracted from heart 1 through the incision in the apex 7. The purse string sutures 34 (not shown for clarity) may also be tightened as the introducer 26 is removed from the incision in the apex 7 to minimize blood loss. Once the introducer 26 has been removed from the shaft 14, the anchor assembly 16 may be advanced along the shaft 14 until the anchor assembly 16 is adjacent to and/or abuts against the apex 7 of the heart 1, for example as generally illustrated in FIG. 24. Additionally, the plunger wire 82 may be disconnected from the plunger 80, for example, by rotating the translator 100 to unthread the plunger wire 82 from the plunger 80.

Turning now to FIGS. 25-28, various views of one embodiment of an anchor assembly 16 are generally illustrated. The anchor assembly 16 (as best seen in FIG. 26 which is a cross-sectional view taken along line B-B of FIG. 27) includes a clamp ring 112, a collar 114, a nut 116, an anchor support 118, and optionally a felt pad 120. The anchor assembly 16 defines a passageway 122 extending therethrough which is configured to receive and be advanced over the shaft 14 of the implant 10. The clamp ring 112, collar 114, and nut 116 are configured to define a compression fitting around a perimeter of the shaft 14, thereby securing the anchor assembly 16 to the shaft 14. In particular, once the anchor assembly 16 is in place (e.g., abutting against the tissue surround the incision site proximate to the apex 7), the surgeon holds the

## 11

anchor support **118** while rotating the nut **116**, thereby compressing the clamp ring **112** and the collar **114** to apply a radially compressive force against the shaft **14**. The radially compressive force secures the anchor assembly **16** to the shaft **14**. For illustrative purposes, the anchor support **118** may have a length *L* of 0.875 cm and thickness *T* of 0.030 cm, and the passageway **122** may have a diameter *D* of 0.116 cm.

To secure the anchor assembly **16** to the heart **1**, the anchor support **118** may be sutured to the heart tissue. The anchor support **118** may include one or more openings **124** and/or arms **126** over which one or more sutures (not shown for clarity) may be passed to stitch the anchor support **118** to the heart tissue, and secure the anchor assembly **16**. The mounting surface **128** of the anchor support **118** may have a curvature which substantially corresponds to the curvature of the heart tissue proximate to the incision site about the apex **7**. The anchor support **118** may optionally be coated/covered/wrapped with pledget material. The pledget material facilitates tissue to growth over the anchor support **118**, thereby further enhancing the connection between the anchor assembly **16** and the heart **1**.

Other anchor assemblies can be used to secure the implant **10** to the heart **1**. For example, a one or more prongs, barbs, staples, clamps, and/or helical screws can be used to secure the implant **10** to the heart. Additionally, the anchor assembly **16** may be eliminated. For example, the implant **10** may be secured to the heart using the shaft **14** which may curl and secured to the heart **1**, for example, using sutures, staples, or the like.

With reference now to FIG. **1**, the implant **10** is shown secured to the heart **1**. Once the anchor assembly **16** is secured to the heart **1**, the shaft **14** may be cut proximate to the anchor assembly **16**. When installed, the spacer **12** is configured to interact and/or cooperate with (e.g., engage) at least a portion of the native mitral valve **3** (e.g., the cusps **4**) to reduce and/or eliminate excessive regurgitation. As such, the configuration and/or geometries of the spacer **12** may depend upon the particulars of the condition of the patient's mitral valve **3** and the damage thereto. In addition, the implant **10** (e.g., the spacer **12** and/or the shaft **14**) has sufficient overall rigidity to maintain the spacer **12** within the mitral valve **3** such that the implant **10** performs as intended.

According to one aspect, the present disclosure features a trans-apical implant. The implant includes a spacer defining spacer cavity configured to be expanded from a retracted position, a shaft extending from the spacer, the shaft defining an inflation lumen fluidly coupled to the spacer cavity and configured to be fluidly coupled to an expansion medium source, and a spacer valve assembly disposed within at least one of the spacer or shaft, the spacer valve assembly configured to allow selectively allow an expansion medium to flow into the spacer cavity to be selectively expand the spacer from a retracted position to an expanded position.

According to another aspect, the present disclosure features an implant delivery system. The implant delivery system includes an introducer having at least one lumen and an implant. The implant is configured to be received in the lumen and includes a spacer and a shaft. The spacer defines spacer cavity configured to be expanded from a retracted position while disposed within the lumen of the introducer. The shaft is configured to extend from the spacer and defines an inflation lumen fluidly coupled to the spacer cavity and configured to be fluidly coupled to an expansion medium source.

According to yet another aspect, the present disclosure features a method of trans-apically delivering an implant within a heart. The implant includes a shaft and a spacer configured to interact with at least a portion of at least one

## 12

cusps of a mitral valve to at least partially restrict a flow of blood through the heart valve in a closed position. The method includes trans-apically advancing an introducer through an incision in an apex of the heart into a left ventricle; advancing the introducer through the mitral valve into a left atrium; advancing the implant through a lumen, defined by the introducer, into the left atrium, wherein the shaft extends within the lumen from the spacer and beyond the incision in the heart; introducing an expansion medium through the shaft to expand the spacer; locating the spacer within the mitral valve to reduce mitral regurgitation; removing the introducer from the heart; and securing the implant to an external surface of the heart proximate to the apex.

As mentioned above, the present disclosure is not intended to be limited to a system or method which must satisfy one or more of any stated or implied object or feature of the present disclosure and should not be limited to the preferred, exemplary, or primary embodiment(s) described herein. The foregoing description of a preferred embodiment of the present disclosure has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the present disclosure to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described to provide the best illustration of the principles of the present disclosure and its practical application to thereby enable one of ordinary skill in the art to utilize the present disclosure in various embodiments and with various modifications as is suited to the particular use contemplated. All such modifications and variations are within the scope of the present disclosure as determined by the claims when interpreted in accordance with breadth to which they are fairly, legally and equitably entitled.

What is claimed is:

**1.** An implant comprising:

- a spacer defining a spacer cavity configured to be expanded from a retracted position;
- a shaft extending from said spacer, said shaft defining an inflation lumen fluidly coupled to said spacer cavity and configured to be fluidly coupled to an expansion medium source;
- a spacer valve assembly disposed within at least one of said spacer or shaft, said spacer valve assembly configured to selectively allow an expansion medium to flow into said spacer cavity to selectively expand said spacer from a retracted position to an expanded position; and
- an anchor assembly configured to be advanced over said shaft and secured to a portion thereof, said anchor assembly further configured to be secured to an exterior surface of a patient's heart.

**2.** The implant of claim **1**, wherein said anchor assembly comprises a compression connection configured to apply a radially compressive force against said shaft to secure said anchor assembly to said shaft.

**3.** The implant of claim **2**, wherein said anchor assembly further comprises an anchor support defining at least one arm over which a suture is stitched.

**4.** An implant comprising:

- a spacer defining a spacer cavity configured to be expanded from a retracted position;
- a shaft extending from said spacer, said shaft defining an inflation lumen fluidly coupled to said spacer cavity and configured to be fluidly coupled to an expansion medium source; and
- a spacer valve assembly disposed within at least one of said spacer or shaft, said spacer valve assembly configured to selectively allow an expansion medium to flow into said

## 13

spacer cavity to selectively expand said spacer from a retracted position to an expanded position;  
 wherein said spacer valve assembly further comprises a plunger configured to be slidably disposed within said inflation lumen, wherein said plunger, when in a first position, is configured to allow said expansion medium to flow into said spacer cavity, and wherein said plunger, when in a second position, is configured to seal said spacer cavity.

5. The implant of claim 4, wherein a portion of said inflation lumen includes a taper which decreases over a length thereof, wherein said plunger is configured to selectively seal and unseal against said inflation lumen depending on the location of said plunger with respect to said taper.

6. The implant of claim 4, wherein plunger is coupled to a plunger wire extending through said inflation lumen in said shaft and beyond a proximal end of said shaft, wherein said plunger wire is configured to selectively move said plunger within said inflation lumen.

7. The implant of claim 6, wherein said plunger wire is threadedly coupled to said plunger.

8. An implant delivery system comprising:

an introducer including at least one lumen;

an implant configured to be received in said lumen, said implant comprising a spacer and a shaft, wherein said spacer defines a spacer cavity configured to be expanded from a retracted position while disposed within said lumen of said introducer, and wherein said shaft extends from said spacer and defines an inflation lumen fluidly coupled to said spacer cavity and configured to be fluidly coupled to an expansion medium source; and

an anchor assembly configured to be advanced over said shaft and secured to a portion thereof, said anchor assembly further configured to be secured to an exterior surface of a patient's heart.

9. The implant delivery system of claim 8, wherein said anchor assembly comprises a compression connection configured to apply a radially compressive force against said shaft to secure said anchor assembly to said shaft.

10. The implant delivery system of claim 9, wherein said anchor assembly further comprises an anchor support defining at least one arm over which a suture is stitched.

11. The implant delivery system of claim 8, wherein said implant further comprises a spacer valve assembly configured to allow said spacer cavity to be selectively expanded.

12. The implant delivery system of claim 11, wherein said spacer valve assembly further comprises a plunger configured to be slidably disposed within said inflation lumen, wherein said plunger, when in a first position, is configured to allow

## 14

said expansion medium to flow into said spacer cavity, and wherein said plunger, when in a second position, is configured to seal said spacer cavity.

13. The implant delivery system of claim 12, wherein a portion of said inflation lumen includes a taper which decreases over a length thereof, wherein said plunger is configured to selectively seal and unseal against said inflation lumen depending on the location of said plunger with respect to said taper.

14. The implant delivery system of claim 12, wherein said plunger is coupled to a plunger wire extending through said inflation lumen in said shaft and beyond a proximal end of said shaft, wherein said plunger wire is configured to selectively move said plunger within said inflation lumen.

15. The implant delivery system of claim 14, wherein said plunger wire is threadedly coupled to said plunger.

16. A method of trans-apically delivering an implant within a heart, said implant including a shaft and a spacer configured to interact with at least a portion of at least one cusp of a mitral valve to at least partially restrict a flow of blood through said heart valve in a closed position, said method comprising:

trans-apically advancing an introducer through an incision in an apex of said heart into a left ventricle;

advancing said introducer through said mitral valve into a left atrium;

advancing said implant through a lumen, defined by said introducer, into said left atrium, wherein said shaft extends within said lumen from said spacer and beyond said incision in said heart;

introducing an expansion medium through said shaft to expand said spacer;

locating said spacer within said mitral valve to reduce mitral regurgitation;

removing said introducer from said heart; and

securing said implant to an external surface of said heart proximate to said apex.

17. The method of claim 16, further comprising:

advancing an anchor assembly over said shaft until said anchor assembly abuts said exterior surface of said heart; and

stitching said anchor assembly to tissue proximate said apex.

18. The method of claim 16, wherein introducing said expansion medium through said shaft to expand said spacer comprises selectively moving a plunger disposed within at least one of said spacer or said shaft to selective seal said spacer.

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